15th Belgian National Day on Biomedical Engineering

Friday November 25th, 2016 at the Royal Academy Palace, Hertogsstraat 1, 1000 Brussel

Theme: Advances in Medical Radiation and Imaging

Programme

08h30  Registration and poster setup + coffee
09h00  Welcome by Prof. Sabine Van Huffel
09h15  Keynote lecture 1 by by Prof. Bart M. ter Haar Romeny:
       ‘Vision for vision’
09h50  Single slide poster presentations Part I hosted by Prof. Stefaan Vandenberghhe
10h15  Keynote lecture 2 by Prof. Hilde Bosmans:
       ‘New developments in x-ray imaging go for improved quality and/or
       reduced patient dose’
10h50  Coffee break + poster session
11h20  Keynote lecture 3 by Prof. John Lee:
       ‘The important role of imaging in guiding photon and photon therapy’
11h55  Single slide poster presentations Part II hosted by Prof. Stefaan Vandenberghhe
12h20  Keynote lecture 4 by Ir. Jennifer Dhont:
       ‘Latest developments in image-guided radiotherapy for respiratory
       motion management’
12h55  Lunch with poster session + industry stands at poster booth
14h20  Company presentations by chair of MedTech Flanders, Karin Scheerlinck
15h20  Keynote lecture 5 by Prof. Steven Laureys:
       ‘Functional neuroimaging’
15h55  Poster awards and drink
16h30  End

Questions or remarks: info@ncbme.be
Website: www.ncbme.be
Facebook page: ncbmebelgium

Organised by the younger committee: Annette Caenen, Zhao Ying Cui, Charlotte Debbaut, Xiao Ya Fan, Markos Kapeliotis, Varun Manhas, Varun Manhas, Florian Salmen, Simon Van Eyndhoven, Dario Farotto, Gerlinde Logghe, Mathias Polffiet, Vincent Van Eeghem
Cochlear Technology Centre, based in Mechelen-Belgium, is a key center of innovation for new technologies, products and processes and thereby contributing to Cochlear’s mission of being the global leader in implantable hearing solutions. The group’s principal activities are designing, manufacturing and selling implantable hearing devices.
Keynote Speakers

Prof. Bart M. ter Haar Romeny
_Eindhoven University of Technology_

Prof. Hilde Bosmans
_KUL_

Prof. John Lee
_UCL_

Ir. Jennifer Dhont
_VUB_

Prof. Steven Laureys
_ULg_
**Keynote lecture 1 by Bart M. TER HAAR ROMENY**

**Curriculum vitae**

Bart M. ter Haar Romeny is full professor of Biomedical Image Analysis at the Department of Biomedical Engineering at Eindhoven Technical University. Before, he was associate professor at the Image Sciences Institute (ISI) of Utrecht University (1989-2001). He received a M.S. in Applied Physics from Delft University of Technology in 1978, did military service (Royal Dutch Navy officer) and acquired his Ph.D. from Utrecht University in 1983. He then became the principal physicist of the Utrecht University Hospital Radiology Department and (1986-1989) clinical project leader of the Dutch PACS project. Research interests: His interests are medical image analysis, its foundations and clinical applications. In order to understand image structure and analysis, a close look is taken to the human visual system. His interests are in particular the mathematical modeling of front-end vision, linear and non-linear scale-space theory, medical computer vision applications, picture archiving and communication systems, differential geometry and visual perception. He authored several papers and book chapters on these issues, edited a book on non-linear diffusion theory in Computer Vision and is involved in (resp. initiated) a number of international collaborations on these subjects.

**Contribution – ‘Vision for vision’**

Diabetes is a world-wide epidemic. The high glycemic levels affect, among others, the blood vessels throughout the body. Especially vulnerable is the retina, and diabetic retinopathy (DR) is one of the main sources of blindness. Early warning and treatment is crucial. An efficient and cost-effective way of DR detection is through quantitative analysis of high resolution optical images from a retinal fundus camera. Such fundus cameras are ubiquitous, and innovative laser-scanning devices enter the market. The RetinaCheck project is a large Sino-Dutch screening project in Northeast China. In China now an alarming 11.6% of the population has developed diabetes, due to genetic factors and fast lifestyle changes. In the project huge amounts of images are acquired, processed and validated against clinical diabetic metadata. Innovative image analysis algorithms have been developed to automatically detect the early biomarkers of disease, inspired by recent insights in the mathematics of functional brain mechanisms, both of visual perception and visual learning, with the ultimate goal of preventing blindness: vision for vision.
**Keynote lecture 2 by Hilde BOSMANS**

**Curriculum vitae**

Hilde Bosmans is a professor & head of the medical physicists in the radiology department of the University Hospitals in Leuven, Belgium. She teaches the medical team as well as the medical physicists at the KU Leuven and at the University of Liège. She obtained her master's degree from the University of Ghent, Belgium, in 1987 and her PhD in biomedical sciences from the KU Leuven in 1992. She is responsible for medical radiation physics in the radiology department of the University Hospitals, in several network hospitals and in private radiology practices. A large part of her activities is devoted to breast cancer screening, its justification and the development of new and better protocols for testing the breast imaging modalities in the 103 mammography units in Belgium. She has also co-authored many internationally accepted quality control protocols. Prof Bosmans’ research interest are quality assurance strategies, perfusion and diffusion MRI of extracranial tumours, optimisation in digital radiology and in particular also in mammography and breast tomosynthesis, phase contrast imaging, cone beam dental imaging and patient dosimetry. She has published more than 192 papers in international journals.

**Contribution – ‘New developments in x-ray imaging go for improved quality and/or reduced patient dose’**

X-ray devices are still in a steady evolution. Technical developments can be used to increase the quality or to reduce the dose to patient or personnel. Both aspects are important and have to be balanced. It is in practice however difficult to find the proper working points and to decide whether y/n investments in particular dose reducing options should be done. Hence, classical tests performed by medical physicists and engineers provide usually only partial answers on the performance that can be reached with a device. The second aspect, the dose to patients or personnel, may require dedicated Monte Carlo simulations, especially if a new imaging technique has to be compared to earlier methods. Next, extrapolating from dosimetry to radiation induced cancer risk is also challenging. Clinical trials can ultimately test a new technology for specific condition. Due to time and financial restrictions, such trials cannot be always performed. We will explain the design of virtual clinical trials to address some of the important issues. We will illustrate their potential to find answers to dose and quality problems for new breast imaging techniques and CT scanning.
Keynote lecture 3 by John LEE

Curriculum vitae

John A. Lee was born in 1976 in Brussels, Belgium. He received the M.S. degree in Applied Sciences (Computer Engineering) in 1999 and the Ph.D. degree in Applied Sciences (Machine Learning) in 2003, both from the Université catholique de Louvain (UCL, Belgium). His main interests are dimensionality reduction, intrinsic dimensionality estimation, clustering, vector quantization, and various aspects of image processing. He is a member of the UCL Machine Learning Group and a Research Associate with the Belgian F.N.R.S. (Fonds National de la Recherche Scientifique). Together with Michel Verleysen, he wrote a monography entitled ‘Nonlinear Dimensionality Reduction’ published by Springer-Verlag in 2007. His current work aims at developing specific image enhancement techniques for positron emission tomography in the center of Molecular Imaging, Radiotherapy, and Oncology (MIRO).

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Personal home page

Publications

2015


2014


• Goossens, Samuel; Senny, Frédéric; Lee, John Aldo; Janssens, Guillaume; Geets, Xavier. Assessment of tumor motion reproducibility with audio-visual coaching through successive 4D CT sessions. In: Journal of Applied Clinical Medical Physics, Vol. 15, no. 1, p. 47-56 (2014). http://hdl.handle.net/2078.1/160133


• Arens, Anne I. J.; Troost, Esther G. C.; Hoeben, Bianca A. W.; Grootjans, Willem; Lee, John Aldo; Grégoire, Vincent; Hatt, Mathieu; Visvikis, Dimitris; Bussink, Johan; Oyen, Wim J. G.; Kaanders, Johannes H. A. M.; Visser, Eric P. Semiautomatic methods for segmentation of the proliferative tumour volume on sequential FLT PET/CT images in head and neck carcinomas and their relation...
Contribution – ‘The important role of imaging in guiding photon and proton therapy’

Historically, radiation oncology has mainly relied on photons, with an increasingly important of imaging to ensure proper targeting of the tumor, while avoiding surrounding organs at risk. Treatment in radiotherapy can indeed be interpreted as a tradeoff between tumour coverage and avoidance of healthy tissues, to prevent both disease recurrence and undesired side effects. In practice, reaching such a tradeoff requires accurate information about the patient morphology, which imaging can provide to some extent. Target volumes, organs at risk, and appropriate safety margins must be drawn in the images before adjusting the angle and modulation of the treatment beams. As typical treatments often span five to seven weeks, morphological changes can occur, like weight loss, organ filling, tumor shrinkage, etc.

Acquisition of new images during the course of treatment can track these changes and be used to re-optimise treatment. Adaptive radiotherapy is currently an active topic of research, in which deformable image registration is a cornerstone. Changes, like breathing motion in particular, can also occur on a much shorter time scale, within a single treatment session. Here too, deformable registration can help to draw specific margins, like an internal target volume or margins around the so-called tumor mid position.

As a few perspectives to end this talk, recent challenges and developments in proton therapy will be briefly illustrated, like fast Monte Carlo dose engines, robust treatment planning, and prompt gamma imaging.
Keynote lecture 4 by Jennifer DHONT

Curriculum vitae

Jennifer Dhont is currently a PhD researcher and teaching assistant at the Vrije Universiteit Brussels (VUB). She obtained a Bachelor of Science in Physics and Astronomy at the VUB in 2012 and a Master of Science in Biomedical Engineering at the VUB in 2014.

Publications


Contribution – ‘Latest developments in image-guided radiotherapy for respiratory motion management’

Driven by technological innovations, radiotherapy has taken in a significant role in the fight against cancer, a disease that has one of the highest mortality rates. As a non-invasive technique with a very high specificity, it is especially beneficial in the treatment of localized disease. This specificity has grown from continuous developments in pursuit of more conformal treatment delivery, bringing to life treatment techniques such as IMRT and proton therapy. However, as radiation delivery has become more focused, the problem of motion rises and blurs the outcome, literally. Respiratory motion exceeding several centimeters, observed in both long, liver and pancreas tumors, nullifies the results of decade long research that tried to shape the dose around the (static) tumour. Instead, the dose is blurred around the target and as such normal healthy tissue is irradiated. Motion management is the general term describing several techniques that try to cope with this motion-issue. These otherwise very
diverse techniques have one main thing in common; imaging. From standard radiography to 4D computed tomography (4DCT) and even MRI, all available options have been consulted.

While many options seem plausible, only a handful have been implemented into the clinic, one of which is real-time tumour tracking (RTTT). With RTTT, the otherwise static treatment beam is moved in real-time, following the motion of the tumour based on external surrogate signals, while verification data of the internal target motion is available in real-time. Prior to the actual treatment, 4DCT aids in the diagnostic as well as in the treatment planning phase.

Unfortunately, this type of treatment is only feasible through the implantation of a fiducial marker in the tumour which enables automatic localization of the target on X-ray images. Studies evaluating the implantation of these markers have reported severe risk for complications, and the presence of possible marker migration with respect to the tumour. Furthermore, this implantation also contradicts the non-invasiveness of radiotherapy. Markerless tumour tracking has therefore been a main topic of investigation.
Keynote lecture 5 by Steven LAUREYS

Curriculum vitae

Steven Laureys MD, PhD, leads the Coma Science Group at the Cyclotron Research Center and Department of Neurology, Sart Tilman Liège University Hospital.

Steven is Clinical Professor (ULg) and Research Director (tenure) at the Belgian National Fund of Scientific Research (FNRS). He graduated as a Medical Doctor from the Vrije Universiteit Brussel Belgium, in 1993. While specializing in Neurology he entered a research career and obtained his M.Sc. in Pharmaceutical Medicine working on pain and stroke using in vivo microdialysis and diffusion MRI in the rat (1997). Drawn by functional neuroimaging, he moved to the Cyclotron Research Center at the University of Liège, Belgium, where he obtained his Ph.D. (2000) and his "thèse d'agrégation de l'enseignement supérieur" (2007) studying residual brain function in coma, vegetative, minimally conscious and locked-in states.

He is board-certified in neurology (1998) and in palliative and end-of-life medicine (2004) and presently is invited professor at the Collège Belgie (Belgian Royal Academy of Sciences) and chair of the "European Neurological Society Subcommittee on Coma and disorders of consciousness".

A recipient of the William James Prize (2004) from the Association for the Scientific Study of Consciousness (ASSC) and the Cognitive Neuroscience Society (CNS) Young Investigator Award (2007), he published several books: The Neurology of Consciousness (with Giulio Tononi, Academic Press, 2008); Coma Science (with Adrian Owen et Nicholas Schiff; Elsevier 2009); Disorders of Consciousness (with Nicholas Schiff, Wiley, 2009) and The Boundaries of Consciousness (Elsevier, 2005).

He is a member of the American Academy of Neurology Committee for the Development of Practice Guidelines for the Vegetative and Minimally Conscious State (2007) (Robert G. Holloway, Dan Larriviere, Michael A. Williams), is Honorary International Fellow of the Royal Hospital of Neuro-disability, London, UK (Keith Andrews) and was invited member of the 2004 Congress on Life-Sustaining Treatments in the Vegetative State organized by the Vatican’s Pontifical Academy of Life (Gian Luigi Gigli) and the 2006 Mohonk Consensus Meeting for the US Congressional Report on Disorders of Consciousness (Joseph Giacino).

Contribution – ‘From Brain to Consciousness. Lessons from Coma and Related States’

The past 15 years have provided an unprecedented collection of discoveries that bear upon our scientific understanding of recovery of consciousness in the human brain following severe brain damage. Highlighted among these discoveries are unique demonstrations that patients with little or no behavioral evidence of conscious awareness may retain critical cognitive capacities and the first scientific demonstrations that some patients, with severely injured brains and very longstanding conditions of limited behavioral responsiveness, may nonetheless harbor latent capacities for recovery. Included
among such capacities are particularly human functions of language and higher-level cognition that either spontaneously or through direct interventions may re-emerge even at long time intervals or remain unrecognized.

When patients in “persistent vegetative state” (recently also coined unresponsive wakefulness syndrome) show minimal signs of consciousness but are unable to reliably communicate the term minimally responsive or minimally conscious state (MCS) is used. MCS was recently subcategorized based on the complexity of patients' behaviors: MCS+ describes high-level behavioral responses (i.e., command following, intelligible verbalizations or non-functional communication) and MCS- describes low-level behavioral responses (i.e., visual pursuit, localization of noxious stimulation or contingent behavior such as appropriate smiling or crying to emotional stimuli). Patients who show non-behavioral evidence of consciousness or communication only measurable via ancillary testing (i.e., functional MRI, positron emission tomography, EEG or evoked potentials) can be considered to be in a functional locked-in syndrome.

An improved assessment of brain function in coma and related states is not only changing nosology and medical care but also offers a better-documented diagnosis and prognosis and helps to further identify the neural correlates of human consciousness. Taken together, recent studies show that awareness is an emergent property of the collective behavior of frontoparietal top-down connectivity. Within this network, external (sensory) awareness depends on lateral prefrontal/parietal cortices while internal (self) awareness correlates with precuneal/mesiofrontal midline activity. Of clinical importance, this knowledge now permits to improve the diagnosis, prognosis and treatment of patients with disorders of consciousness, which currently remains very challenging. New technological advances now also permit to show command-specific changes in fMRI, EEG or eye-pupil measurements providing motor-independent evidence of conscious thoughts and in some cases even of communication. We will conclude by discussing related ethical issues and the challenge of improving our clinical care and quality of life in these challenging patients with disorders of consciousness.
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### Tissue Engineering

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Biomechanics
BIMANUAL CORRECTIVE RESPONSES ARE DRIVEN BY THE BIOMECHANICS OF THE UPPER LIMBS

David Córdova Bulens 1,2,*, Frédéric Crevecoeur 1,2, Jean-Louis Thonnard 1,3, Philippe Lefèvre 1,2

1 Institute of Neuroscience (IoNS), Université catholique de Louvain, Brussels, Belgium.
2 Institute of Information and Communication Technologies, Electronics and Applied Mathematics (ICTEAM), Université catholique de Louvain, Louvain-la-Neuve, Belgium.
3 Physical and Rehabilitation Medicine Department, Cliniques Universitaires Saint-Luc, Brussels, Belgium

Keyword(s): biomechanics

1. INTRODUCTION

Bimanual tasks involve coordination of both arms, which often offers redundancy in the way task success can be achieved. Understanding how the nervous system distributes control across limbs is often considered from the perspective of handedness [1]. In this context, studies have shown that the brain tends to favor the dominant arm when performing bimanual movements. We previously showed that biomechanics influence motor planning during a bimanual task. Here, we look at bimanual corrective responses to perturbations.

2. MATERIALS AND METHODS

The task consisted in producing a 20 N force using both arms towards visual targets representing the resultant force in the horizontal plane. Visual feedback was provided by mapping the sum of forces applied on the fixed robotic interface onto cursor motion in a virtual reality display (KINARM, BKIN Tech., Kingston, Canada). The force distribution across arms was unconstrained. Eight different directions of force production were tested. In 80% of the trials, the cursor jumped when it reached the midway point of the movement. The cursor jumped perpendicularly to the movement direction. Therefore participants needed to correct the cursor movement by adjusting the forces produced by their arms. Jumps of plus minus 3 or 5 cm were tested.

We extracted the baseline forces produced at target reach by each arm for all targets from the forces measured during the unperturbed trials. The baseline force distributions of all subjects were in line with predictions from a human-inspired model driven by an optimal control policy [2]. In the tested configuration, participants pushed more with their left arm in the 2nd and 4th quadrants and more with their left arm in the 1st and 3rd quadrants.

3. RESULTS AND DISCUSSION

The forces produced by each arm during the perturbed trials were compared to the baseline trials. The results showed that corrective force responses to perturbations were strongly influenced by the biomechanics of the upper-limbs with corrections changing dependent on the direction of the target and of the perturbation in a way that is compatible with the forces produced in unperturbed trials.

The forces of each arm were adjusted in a way that paralleled the weighting of each arm during unperturbed trials. For instance, for a target placed in the direction of the midway line of the participants and closer to their body, the force of each arm changed for rightward or leftward perturbations. When having to perform a rightward corrective cursor movement, the left arm produced more force than in the baseline trials whereas the right arm produced less force than in the baseline trials. Inversely, when having to perform a leftward corrective movement, the left arm produced less force than in the baseline trials whereas the right arm produced more force than in the baseline trials.

These results show that the mechanism that optimally distributes mechanical efforts across limbs is shared across planning and control stages of bimanual control.

References


NEEDLE PENETRATION AND MECHANICAL CHARACTERISATION OF UPPER GI TRACK SOFT TISSUES

Victor Costenoble1*, Jean-Charles Larrieu1,2, Nicolas Geuens1, Benjamin Conradt1,2, Alain Delchambre1,2

1Université Libre de Bruxelles, Bio-Electro and Mechanical Systems Department, Belgium
2 Université Libre de Bruxelles, Laboratory of Experimental Gastroenterology, Belgium

Keywords: biomechanics – medical/clinical engineering

1. INTRODUCTION

Endoscopic procedures in the upper GI Track tend to be more and more common. These minimally invasive procedures evolved from only being a diagnostic tool to surgical techniques. They allow a less painful and faster recovery to the patient. In order to be effective and to perform different kinds of operations, the development of new cutting-edge tools has become mandatory. These tools must be small enough (generally below 4 mm) to fit inside the operating channel of the endoscopes. Many devices use needles to penetrate inside soft tissues, either for injecting liquids or for suturing. In both cases, it is critical not to damage the surrounding environment or penetrate too deep inside the targeted zones. Hence, this research focuses on the study of needles penetration inside soft tissues, of the force required to pierce the tissues, and the identification of the different layers of a given region.

2. MATERIALS AND METHODS

The experimental set-up consists of a Lloyd Instruments LS1 test bench along with a 10N load cell. The needle is connected to the load cell and the soft tissues are strongly clamped to the base of the bench using a homemade clamp 3D printed using an Eden 260V from Stratasys, Ltd. The upper GI track tissues were obtained from the slaughterhouse of Charleroi, Belgium, and removed from newly slaughtered pigs.

The characterization of the soft tissue penetration was divided in two main steps. Injection hollow needles [1] were selected. The influence of the needle bevel was quantified testing three bevels (normal, short and extra-short) keeping a constant needle diameter and equal to 22G (0.644mm). In a second time, the influence of the needle diameter was quantified using a short bevel needle for different needle diameters as well as different insertion speeds. Finally, the best combination of needle bevel and diameter with a speed of 5mm/s, approximating the manual insertion of a needle [2] was chosen and tested.

3. RESULTS AND DISCUSSION

Promising preliminary results are presented in Figure 1 for the insertion of three needle diameters at a constant speed. The 23G needle, logically requires the lowest insertion force and exhibits the lowest standard deviation. Current investigations are focused on identifying the successive layers of the soft tissues in order to develop polymeric phantoms mimicking the mechanical response of the upper GI track soft tissues.

![Figure 1: Force Vs Position graph obtained for three diameters (16G (1.29mm), 19G (0.912mm), 23G (0.573mm)).](image)

References


AGEING IS LEADING TO ALTERATIONS IN MURINE CORTICAL BONE MICROPOROSITY

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Keyword(s): biomechanics – medical imaging

1. INTRODUCTION
Osteoporosis is an age-related disease that affects millions of people. It is characterized by a systemic impairment of bone mass and deterioration in bone microarchitecture resulting in fragility fractures. It has been postulated that bone’s microporosity plays key biological and mechanical roles. Considering that mechanosensitivity is changing with aging [1] we hypothesized that bone microarchitecture at old age would differ from that at young age.

2. MATERIALS AND METHODS
We used desktop micro-computed tomography (µCT) for 3D visualization and morphometric analysis of mouse cortical bone porosity at different hierarchical levels as a function of age. The fibular midshaft of 6 young-adult (5-months) and 6 old (23-months) female C57BL/6 mice were imaged nondestructively using µCT (SkyScan 1172, Bruker) at nominal resolutions of 5 and 0.7 micrometer to quantitatively determine the 3D morphology of cortical bone microstructure at macro and micro levels, respectively. Figure 1 shows 3D renderings of representative volumes of interest for analyses at the macro-level (a) and micro-level (b).

3. RESULTS AND DISCUSSION
At the macro-level, 5-months bones exhibited significant differences (p<0.05) in total tissue volume, cortical bone volume density, mean periosteal and endosteal perimeter compared with 23-months bones. At the micro-level, we concluded that aging results in significantly decreasing canal number density (p<0.001) and canal volume density (p<0.01) with no significant variations in the mean canal length and diameter. The mean canal number density at 23 months of age (90 mm⁻³) was significantly lower than that at 5 months of age (242 mm⁻³). No significant differences were found in lacuna number density and lacuna volume density. In old bones, mean lacuna volume (243 µm³) was significantly (p<0.05) smaller than in young bones (279 µm³). Furthermore, the shape of the lacunae changed from flat in young age to more round at old age. Our hypothesis was confirmed: in mice, bone microarchitecture at old age differs from that at young age. The biological implications will be subject of further study. Furthermore, microCT-based 3D visualization and quantification of cortical bone microstructure can enhance our understanding of the role these features play in bone modeling and remodeling during aging.

Figure 1: 3D renderings of representative volumes of interest at the macro-level (a) and micro-level (b).

References
AUTOMATIC DETERMINATION OF SOFT TISSUES
PROPERTIES DURING MECHANICAL TESTS

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Keywords : biomechanics – medical/clinical engineering

1. INTRODUCTION

In an intact human joint, soft tissues (ligaments and tendons) are involved in different ways. They provide joint stability as well as force and motion transmission [1]. They usually present non-linear stress-strain curves, and their properties depend on the applied load and strain rate [2]. These materials also have anisotropic properties along their length. Unfortunately, no standard guidelines have been defined yet on the best practice to mechanically characterize these soft tissues. Hence, this study aims is to develop an algorithm that will automatically determine the mechanical properties of the soft tissues during a tensile test.

2. MATERIALS AND METHODS

The experimental set-up consists of a Lloyd Instruments LS1 test bench equipped with a 250 N load cell. Using the ASTM-D638 standard, dogbone samples of a known silicone material, (Ecoflex 00-50 [3]) were molded and used to calibrate and prove the relevance of the method before applying it to a pig’s Achilles tendon. The sample was patterned with square markers and then attached between the clamps. A camera was positioned in front of the specimen with an acquisition frequency set to 33 mHz. The measurement of the distance between the markers allowed the real-time monitoring of the material deformation while getting rid of the errors coming from the eventual slipping of the material between the clamps. It was also possible to quantify the difference in terms of mechanical properties between the different parts of the soft tissues (near the bone or muscle, central part for the biological soft tissues) by computing the distance between the different markers.

3. RESULTS AND DISCUSSION

The procedure was reliable for both synthetic and biological soft tissue materials. Figure 1 shows an average difference of 32% between the value of the clamps and the markers displacement, hence validating the reliability of the procedure to exclude the effect of slipping during the measurement when calculating the true stress in the material.

Figure 1: Material characterization (stress) provided by the test machine (plain blue curve) and determined by using the contactless approach (dotted red curve).

The tensile tests on the pig’s Achilles tendons resulted in a rupture at an average strain of 20% with an average stress of 0.12 MPa and a maximum error of 3%. The elastic response of the soft tissue behavior was modeled using the 3 and 5 parameters Mooney-Rivlin models, shown in Figure 2 with a squared two-norm residual of 10-4. Currently, tests are performed on human soft tissues (knee tendons and ligaments).

Figure 2: Stress Vs Strain characteristic of the tensile test on a pig Achilles tendon. a) experimental curve, b) 3 parameters and 5 parameters Mooney-Rivlin model, respectively in dashed, continuous and dash-dot lines. The stretch is defined as (1+Strain).

References


PLANTAR PRESSURE-BASED ESTIMATES OF FOOT KINEMATICS DURING GAIT – OPTIMIZATION APPROACH

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Keyword(s): Biomechanics

1. INTRODUCTION
Currently, instrumented gait analysis is becoming an important tool to evaluate ankle-foot pathologies and to prescribe proper treatment [1]. It is most often performed using integrated 3D-Motion Analysis Systems (MAS) which involve a large variety of technologies. However, ankle-foot specialists tend to rely mainly on plantar pressure data to evaluate foot pathologies. Plantar pressure only provides information on the pressure distribution perpendicular to the two-dimensional grid in the plate. Although relevant to detect local tissue overloading, to date, this information cannot be used to evaluate ankle-foot kinematics. This work focusses on enhancing the possibilities of plantar pressure evaluation, expanding the analysis to include evaluation of ankle-foot kinematics, thereby increasing its evaluation potential.

2. MATERIALS AND METHODS
2.1 Marker set protocol and acquisition
Experimental data was collected in one healthy subject during a single trial. The motion capture data were collected using ten infrared Vicon cameras (Vicon, Oxford Metrics, UK) to track the motion of 20 skin-mounted markers (13 positioned on the foot) at a sampling rate of 200Hz [2]. Synchronized plantar pressure data were collected (RSscan International NV) at a sampling rate of 500Hz.

2.2 Foot Musculoskeletal Model
The extended foot model is composed of six rigid bodies, see Fig. 1, interconnected by 14 degrees of freedom (DoF) [3].

2.3 Contact Model
An elastic foundation contact model (EFM) [4] is added to the musculoskeletal foot model in order to simulate the plantar pressure. The contact geometries are represented by triangular meshes obtained by a least-squares ellipsoid fitting optimization [5] to the different regions of interest (calcaneus, midfoot, forefoot and toes) that were in contact throughout the trial. The ellipsoids are initially positioned in the foot model using an empirical anatomical approach

2.4 Optimization Algorithm
This method optimizes the foot model kinematics using a time step per time step approach. The kinematics are used to simulate the plantar pressure and the virtual marker positions which are respectively compared with the measured plantar pressure and marker positions. The correspondence between measurements and simulations is maximized.

3. RESULTS AND DISCUSSION
Joint angles for the main foot DOF’s were obtained using only a cluster of reflective markers at the tibia, one marker at the calcaneus and another at the toes. The presented optimization algorithm allows to estimate foot kinematics using pressure distribution and limited marker information. It enhances the possibilities of using pressure distribution to access pathologies and treatments. In the future, the reflective markers will be replaced by accelerometers to simplify the acquisition process and to enable the quantification of foot kinematics in standard clinical practice.

References
AN EXPLORATIVE CFD STUDY ON STENOSIS-INDUCED FLOW INSTABILITIES IN THE CAROTID ARTERY

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Keywords: biomechanics – modeling of physiological systems.

1. INTRODUCTION

Flow bench studies on stenosed models embedded with tissue mimicking gels, e.g. Polyvinyl alcohol (PVA), demonstrate that stenosis-induced flow instabilities and pressure fluctuations may lead to mechanical waves which propagate through soft tissues and can be detected by means of non-invasive diagnostic tool such as laser Doppler vibrometry (LDV). Computational Fluid Dynamics (CFD) may provide a complementary tool to better understand stenosis flow related phenomena and provide insights into this diagnostic method.

2. MATERIALS AND METHODS

An MRI scan of a carotid bifurcation allowed us to obtain a patient specific case, with a maximum area stenosis of 82% in the Internal Carotid Artery (ICA). The geometry was 3D printed in compliant material and later embedded with PVA cryogel to mimic neck’s tissues. The model was tested by means of LDV and pressure transducers, located downstream of the stenosis, for multiple flow settings. The applied Reynolds numbers (Re) ranged between 550 and 1100. Initial CFD simulations were performed by means of a commercial fluid solver (Fluent, Ansys) on a 440K hexahedral grid through time-dependent 3D Large Eddy Simulations (LES). The Smagorinsky-Lilly constant (Cs) was set equal to 0 in order to nullify the viscosity added by the model. Bounded schemes were used for the momentum and for the transient formulation. In order to replicate in-vitro tests, the highest pulsatile flow was applied at the inlet by means of User Defined Function. Moreover, to mimic also the in-vivo conditions, the outflow boundary was set as 32% flow ratio for the ICA [1]. Particular attention was given to the choice of the computational time step size (7e-5 s), which was set in order to both match the in-vitro sampling frequency and respect the Courant–Friedrichs–Lewy (CFL) condition.

3. RESULTS AND DISCUSSION

Pressure instabilities were observed downstream of the stenosis, where the flow diverges and decelerates. The amplitude of pressure oscillations was obtained by means of frequency analysis of the discrete signal (Fast Fourier Analysis, FFT). Highest frequency peaks were observed 2 to 4 diameters downstream of the stenosis, revealing peaks in the 10-450 Hz frequency band.

These initials CFD results are in line with previous studies with similar models and our own experimental observations. Further analysis will be performed at different flow rates, shape and degree of stenosis. The sensitivity of the results to the mesh density and to the time step will be further explored. The computational method and the in-vitro techniques are currently further investigated.

The integrated experimental-computational approach will provide further details on fluid dynamics and mechanical phenomena, providing subsequently guidance for studies on patients.

Acknowledgements

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References

PERSONALIZED MUSCULOSKELETAL MODELING OF SPINAL DEFORMITIES BASED ON STEREORADIOGRAPHIC IMAGES FOR BIOMECHANICAL ANALYSIS OF MOTION

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Keywords: biomechanics – medical imaging

1. INTRODUCTION

Adult Spinal Deformity (ASD) is present in 68% of the population older than 60 years [1]. Surgical treatment aims at stabilizing the deformed spine which, apart from preventing curve progression, also aims at achieving a balanced spinal posture and reducing back pain. Although, surgery is associated with more positive outcome compared to non-surgical treatment, up to 70% of ASD patients suffer from post-operative complications [2]. This high complication rate is expected to be closely linked to a conceptual lacuna in the clinical evaluation process, and specifically in the lack of knowledge about how ASD impacts the locomotor system [3]. Since most pain and complaints for ASD patients arise during dynamic activities of daily living, the use of static medical image-based assessment approaches alone fails to describe the functional ability during these activities. Therefore the insights into the impact of the deformity itself as well as its treatment are severely limited. Musculoskeletal modeling and simulation has clear potential to fill this knowledge gap. Through these techniques, the functional ability of spine patients can be assessed in terms of muscle and contact forces during motion. Unfortunately however, applying multi-body simulation in ASD is currently not possible, as most available musculoskeletal models (MSMs) do not allow to include the effect of spinal deformities on musculoskeletal geometry. Therefore, the aim of this research project is to develop a software platform for radiograph-based subject-specific modeling of the spine.

2. MATERIALS AND METHODS

Using the state-of-the-art generic model of Bruno et al. [4] as a basis, the modeling platform allows for custom-made, manual routines to adjust the size and pose of the included bone models, based on biplanar x-ray images (fig. 1), acquired using the EOS Imaging system (EOS Imaging, France), which is considered as ground truth. The modeling platform further allows the identification of reflective markers and the definition of their position relative to the underlying bony segments and has fully functional import and export links to the OpenSim simulation platform (SimTK, Stanford, fig. 2). Following ethical approval and informed consent We applied the workflow to a subject with ASD (49y, male, 71kg), obtaining a subject-specific model. Furthermore we applied the standard approach of marker-based scaling of the generic model (fig. 3). This subject underwent 3D motion analysis using a motion capture system (Vicon Nexus, Oxford, UK). Next, both models were compared statically and dynamically through MSM simulations.

3. RESULTS AND DISCUSSION

Using the developed modeling platform, the need for subject-specific MSMSs is confirmed as the currently available generic musculoskeletal model failed to accurately represent spinal deformity using the standard approach of marker-based scaling (fig. 3 vs. fig. 4). Furthermore, the potential of image-based marker personalization was demonstrated as a means of correcting palpation errors. Finally, the estimated vertebral compressive loading and muscle activations using dynamic simulations of spine motion were found to be very sensitive to the vertebral alignment in the MSM used.

References

A NOVEL MULTIPLANE SCANNING STEREO PIV TECHNIQUE TO INVESTIGATE LEFT VENTRICULAR FLOW

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Keyword: biomechanics

1. INTRODUCTION

Various experimental studies have been conducted to obtain a better understanding of the flow field in the left ventricle (LV). In particular, in vitro PIV studies have been performed to investigate the flow field in a 2D plane [1], or to reconstruct the 3D flow structures numerically from 2D velocity data [2].

The intraventricular flow, however, has a highly complex and unsteady fluid structure. In this work, we therefore present a novel experimental setup which allows 3D volume reconstruction of the flow field in a transparent LV membrane model.

2. MATERIALS AND METHODS

2.1 Stereoscopic scanning PIV

The developed multiplane scanning Stereo PIV system, consisting of two CCD cameras, is capable of acquiring the 3D velocity field within a volume of 80*70*80 mm³ by assembling the velocity data from several parallel measurement planes. The cameras, the pulsed Nd:YAG laser and the external housing have been rigidly connected to a traversing mechanism equipped with a stepper motor. To eliminate the need to perform the complex and time consuming calibration in each measurement plane separately, the LV membrane is mounted inside the internal fixed transparent tank. This proposed system, partly based on the work of Yagi and co-workers [3], is further referred to as the 'Double Windows Prism' system.

2.2 Working fluid and cardiac cycle

A cardiovascular simulator was used to impose different physiological pressure and flow conditions. Mechanical bileaflet valves were mounted in the aortic and mitral position. A three component fluid consisting of sodium iodide, glycerol and distilled water (volume fraction 79:20:1) was used as a blood mimicking fluid.

3. RESULTS AND DISCUSSION

The aim of this work was to develop an experimental PIV system that would allow us to reconstruct the 3D LV flow field in different controllable and repeatable conditions. Figure 1 shows a preliminary reconstruction of the flow in the LV, obtained after interpolating the velocity data from several parallel planes (distance 2 mm). The images were obtained in a phase-locked manner through 100 pulsatile cycles during late diastole. We believe that this experimental setup will facilitate the interpretation of the complex LV flow and serve as a reference for in vivo and numerical studies.

Figure 1: 3D streamlines in LV sac during the late diastole (A). The velocity vector field in one plane (B); the vectors (in black) represent the velocity magnitude, and the out-of-plane velocity component is color coded.

References


BIOMECHANICS OF MECHANICAL WAVE PROPAGATION THROUGH SOFT BIOLOGICAL TISSUES

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Keyword: biomechanics

1. INTRODUCTION

The dynamics of the heart and its generation of pressure waves in the arterial system create mechanical disturbances that propagate as compressional and shear waves through the tissues (muscle and fat) to the skin surface, where they induce low amplitude displacements and vibrations that can be detected (e.g. with laser Doppler vibrometry) [1]. These signals might bear diagnostic and prognostic information, e.g., on the propagation speed of the pressure pulse in arteries (pulse wave velocity) or cardiac dyssynchrony [2]. Skin vibrations might also reveal the presence of stenosis because of high frequency fluctuations induced by flow disturbances in superficial arteries. The physics of these mechanical waves is not well understood, and the accuracy, the sensitivity and the specificity of potentially novel diagnostic methods based on the assessment of the skin vibrations, are not known.

2. MATERIALS AND METHODS

An integrated experimental-numerical approach is taken. Experimental models include: i) hollow cylindrical structures in homogenous tissue mimicking material (TMM) subjected to forced oscillations and ii) a stenotic carotid artery model, representative of the human anatomy and physiology, embedded within TMM. Experimental TMM phantoms were made in poly vinyl alcohol (PVA) gel, prepared by adding granulated PVA to deionised water and stirring the mixture while heating to 90 °C. After one freeze-thaw cycle, the phantoms exhibit quasi-static elastic properties similar to those of biological tissues (10⁴ -10⁸ Pa). Computer modelling was performed in Abaqus/Explicit (Abaqus 14.1). Constitutive material model parameters (linear visco-elastic material model through Prony series coefficients definition) were derived from experimental measurements, and boundary conditions, deduced from the experiments. After validation of the PVA constitutive model through the comparison of computational and experimental displacement induced by forced oscillation in the cylindrical structure, the model with the embedded carotid was used to simulate the propagation of mechanical waves, generated by the flow conditions, through the PVA gel up to the external surface.

3. RESULTS AND DISCUSSION

Cylindrical computer models reproduced a similar displacement pattern to that of the experimental set ups and the effect of different material model coefficients was investigated. Preliminary results of the embedded carotid artery show waves travelling through PVA gel and reaching the top surface of the gel. Displacement patterns generated by the pressure pulse were compared for different values of pressure amplitude and frequency. The proposed integrated experimental-computational approach will provide insights into the physics of mechanical wave propagation in soft biological tissues and explore the theoretical limits of diagnostic techniques based on skin surface vibrations. This will then provide a tool and framework to analyse and understand measured vibration patterns in vitro and in vivo.

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References

MATRIX: IN SILICO AND IN VITRO MODELS OF ANGIOGENESIS

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Keywords: biomechanics – modeling of physiological systems

1. INTRODUCTION
Theoretical studies and experimental observations increasingly demonstrate the importance of mechanical forces sensed and exerted by cells in morphogenesis[1]. Understanding the role of forces in signaling, evolution of cellular contacts, and migration will help elucidate mechanisms in multiple multicellular phenomena. The formation of new vessels from existing vascular tissue, angiogenesis, presents a relatively simple yet inherently a multi-scale system in which a few cells align and migrate coordinately to form a sprout. Its characterization must account for changes in mechanical properties of the extracellular matrix (ECM) with cellular remodeling, as well as mechanotransduction in cell-ECM complexes or focal adhesions (FAs) and cell-cell adhesion complexes or adherens junctions (AJs). Computational modeling of individual cells with dynamic adhesion will permit simulation of endothelial cell chain migration and shuffling, the process by which cells are rearranged within a sprout. The latter is a process necessary for growth of the sprout, and no current model explores the role of mechanical deformation of cells in it. Temporal and spatial correlations between migration, concentration of molecules involved in Notch and FAK-p130Cas-Rac signaling, and traction forces can reveal the relevance of each component to sprouting.

2. MATERIALS AND METHODS
The MAtrix project at KU Leuven is an interdisciplinary effort to characterize cell-ECM forces through both in silico and in vitro studies. Theoretically, a discrete element method (DEM) technique is used to model individual cells[2]: A lattice-free particle-based method is used to describe the cell surface in 3D by projecting a triangular mesh on to the surface. Cellular mechanics is described by modeling the cortex by means of viscoelastic elements connecting the nodes of the mesh (finite extensible non-linear elastic spring in parallel with a dashpot) and using an elastic bending force between neighboring triangles. Dynamics and mechanical forces of cell-ECM contacts are simulated based on experimental measurements. Experimentally, traction force microscopy (TFM) is implemented in the study of models of human umbilical vein endothelial cells (HUVECs) in 3D collagen gels[3]. TFM is performed through confocal microscopy. The ECM will be visualized through second harmonic generation (SHG).

3. RESULTS AND DISCUSSION
Our findings will provide insight into the mechanisms of sprouting. These are applicable to tissue engineering, where directed angiogenesis for proper tissue oxygenation has proved elusive. These mechanisms, once properly understood, can also be disrupted. This has therapeutic use as it can be used to hinder tumor growth and thus cancer progression.

References
Biosignals
ACTIVITY RECOGNITION FOR PHYSICAL THERAPY
MOVING TO THE HOME ENVIRONMENT

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Keyword(s): biosignals

1. INTRODUCTION

In physical therapy, the therapist is often interested in the functional capacity of the patient i.e. the ability to perform a certain task. Nowadays, this is assessed using a patient-reported (hence subjective) questionnaire such as the Bath Ankylositis Spondylitis Functional Index (BASFI) \cite{2}. The questionnaire lists transitory activities used in therapy. Before or after performing the exercises in a therapy session, the patient scores his or her ability to perform it.

However, these activities are typically also performed in the home environment, even as part of daily life. As a first step towards the assessment of functional capacity at home, the relevant activities should be recognized. Secondly, they should be assessed objectively in an interpretable way, as an alternative to the current subjective evaluation. This work focuses on the first aspect.

Accelerometry has been used extensively for activity recognition \cite{1}. Yet, it mostly focuses on recognition of repetitive activities or poses (e.g. walking, sitting), whereas the transitions are more informative in physical therapy.

2. MATERIALS AND METHODS

28 patients suffering from axial spondyloarthritis were equipped with a SenseWear Armband (2-axial accelerometer sampling at 32Hz). It was mounted at the upper (dominant) arm to capture both full-body and peripheral movement. Then, the patients performed a series of ten activities derived from the BASFI questionnaire, supervised by a physical therapist. The activities included e.g. sit-to-stand, maximal reach, getting up, lying down and picking up a pen (Figure 1).

Recognition of these activities is achieved through a two-step approach. In a first step,

**Figure 1:** Sensor and example of activities

activity segments are segmented, discarding other parts of the continuous acceleration signals.

The second, actual recognition step compares and combines two approaches to classify segmented activities: direct pattern matching yielding similarities through Dynamic Time warping (DTW) and statistical features. Similarities and features are used as inputs in a Linear Discriminant classifier in a leave-one-subject out paradigm train-test setting.

3. RESULTS AND DISCUSSION

Combination of the DTW and statistical features yields significantly superior performance compared to each of them separately, with an average accuracy up to 93.6%.

These positive results pave the way for the next stage, the automatic and interpretable assessment of functional capacity, the subject of currently ongoing research.

References


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COMPARISON OF TONIC-CLONIC SEIZURE DETECTION USING HEART RATE, ACCELEROMETER AND EMG

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Keyword(s): biosignals

1. INTRODUCTION

Automated epileptic seizure detection in a home environment has become of increasing interest the last couple of decades. Tonic-clonic (TC) seizures are the most clinically dangerous type of seizures. Due to their clear clinical behavior, it is possible to detect these seizures with three different modalities. The tonic phase leads to sudden stiffening of the muscles, which can be detected with the electromyogram (EMG). The clonic phase results in strong alternating movements, and can therefore be detected with an accelerometer (ACM). The autonomic nervous system changes during both phases, which can be seen in a big increase in the heart rate (HR). All these modalities can be acquired easily at home using currently available wearables, but the question is which modality/sensor is the most suited for uni- and multimodal TC seizure detection at home?

2. MATERIALS AND METHODS

Data from 7 pediatric patients with 22 TC seizures longer than 10s were recorded at the Pulderbos Rehabilitation Center for Children and Youth, leading to in total 252 hours of nocturnal data. The recordings contain data of single-lead electrocardiogram (ECG), 1 EMG sensor at each arm and 1 ACM sensor on each wrist/ankle.

The unimodal EMG and ACM seizure detection algorithms extract different features from a 2s window and classify them using least-squares support vector machines (LS-SVM) [1].

The HR-based seizure detection algorithm searches for strong HR increases caused by a change in the autonomic nervous system. If such a HR increase is found, multiple HR features are extracted from this time period and classified using a SVM classifier.

3. RESULTS AND DISCUSSION

The single-sensor EMG and ACM algorithms gave the best combination of sensitivity and false alarm rate for sensitivities up to around 70%. For higher sensitivity values, the HR algorithm resulted in a better performance compared to the EMG/ACM algorithms. The HR algorithm was able to detect all seizures with only 0.9FP/h, whereas for the other single-sensor algorithms this resulted in at least 3FP/h. Some seizures had very short tonic or clonic phases, making it hard to detect them accurately with only the ACM or EMG sensors. Some limbs were also not affected or obstructed during certain seizures, making it hard to detect them using only the corresponding ACM/EMG sensor. The HR however increased strongly during both phases and is not affected by the clinical outcome of the seizure, allowing to detect more seizures with a reasonable false alarm rate. All single-sensor seizure detection algorithms resulted in an average detection delay of 15-20s.

Combining different modalities resulted in strong performance increases, typically leading to nearly 10 times less false alarms for each added sensor. The HR+ACM combination showed to work the best on the inspected dataset.

The results show that using EMG/ACM might be better for the clinical clear TC seizures, but ECG is more reliable for seizures with short tonic/clonic phases. Multiple modalities/sensors are however needed in order to get a false alarm rate that is acceptable for usage in practice.

References

INCREMENTAL LEARNING FOR ONLINE EPILEPTIC SEIZURE DETECTION USING HEART RATE

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Keyword(s): biosignals

1. INTRODUCTION

The quality of life of people suffering from refractory epilepsy could be improved by a continuous home monitoring system that detects seizures and alerts a caregiver. Previous studies have observed ictal tachycardia in certain types of seizures, mainly in temporal lobe epilepsy [2]. Therefore heart rate (HR) changes could be used to automatically detect seizures in real-time. These heart rate changes are however very patient-dependent, so a patient-specific detector would be ideal. It can however take multiple days before enough training data is available to get a reliable detector. Therefore a detector that starts patient-independently and incrementally grows to a patient-specific system is proposed. One-class support vector machine (SVM) is used as classification model.

2. MATERIALS AND METHODS

Nocturnal electrocardiogram (ECG) data were recorded at the Pulderbos Rehabilitation Center for Children and Youth. 863 hours of data were obtained over 73 nights on 16 pediatric patients suffering from tonic-clonic and hyperkinetic frontal lobe seizure.

Significant heart rate increases are automatically detected from the ECG signal. 31 features are extracted from each increase. Feature selection resulted in the use of the length, amplitude and slope of the HR increases, the maximal HR and the Hjorth parameter activity on the baseline.

With these features a patient-independent one-class SVM is built. This one-class classifier has as advantage that it only models one class, in this case the normal HR increases. Seizures are seen as outliers to this class, no seizure data is needed to train this classifier. This implies that no user feedback is needed to update the model. The classifier is updated online each time a new HR increase is detected. As such the classifier incrementally grows toward a patient-specific classifier. The updating is based on the algorithm developed by Bordes et al. for two-class SVM, which was adapted to the one-class case [1].

3. RESULTS AND DISCUSSION

The patient-independent classifier gives a sensitivity of 78.22% and a positive predictive value (PPV) of 6.11%. The missed seizures mainly are shorter than 10 seconds. This is not enough time to create a significant HR increase, which makes it difficult to detect these seizures. The classifier tried to detect them and in doing so created 1.7 false positives per hour (fpph) which explains the low PPV.

The patient-specific classifier has a sensitivity of 77.23% and a PPV of 6.46%. As expected the amount of false positives decreased without altering the sensitivity much. This drop in false positives to 1.6 fpph is however limited. This can partly be explained by the large time in between successive measurements of the same patient and the limited amount of data per patient. Another factor is the high complexity of the patient-independent classifier, the decision boundary is defined by too many support vectors which results in a slow adaptation of the model.

The proposed method is able to learn from patient-specific data without the need of user feedback. This is a great advantage since this feedback is not always as reliable.

References


STUDY OF TRANSITION FROM INTERICTAL TO Ictal: 
INSIGHT FROM A COMPUTATIONAL MODEL 

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Keyword: biosignals

1. INTRODUCTION

Electroencephalography (EEG), or intracranial electroencephalography (iEEG) is one of the most widely used tools in epilepsy research, as it is able to capture electrical activity directly from the cortical cortex. The neurophysiological mechanisms underlying such depth EEG is crucial to progress in the understanding seizure genesis. In this paper, a neural mass model[1] was fitted to real iEEG epileptic signals and key parameters (average excitatory synaptic gain of the main population, and average slow/fast inhibitory gains of the slow/fast inhibitory interneuron populations) were identified within a sliding window by exhausted search. Then time evolution of important indicators calculated from the identified parameters were analyzed. Visual analysis implies a clear increase of two indicators at seizure onset for most recordings.

2. MATERIALS AND METHODS

The model used to simulate the EEG in this study was proposed by Wendling et al. [1]. The parameter space was sampled around standard values: Ae (excitatory) was varied from 3 to 7 mV with a step of 0.125mV, B (slow inhibitory) and G (fast inhibitory) were varied from 0.5 to 50, with a step of 0.5 mV. For each triplet, simulations were repeated to generate 15 synthesized signals. Then, features [2] of the 15 signals were extracted and the mean of each feature was obtained. The recorded iEEG was firstly filtered and normalized by variance. Then it was processed with a sliding window of 2 seconds with 50% overlap. For each time window, the feature vector was obtained and Euclidean distance with averaged feature vector calculated for each triplet in the parameters space was obtained. Then an exhausted search was performed and the best 50 candidates were chosen from the parameter space for further analysis. Thirteen iEEG recordings from four patients were processed in this study. Important indicators (Ae/B, Ae/G, B/G and Ae/(B+G)) were obtained from the selected candidates for each time window. The means, as well as the medians were obtained. The time evolution of each indicator was analyzed for all recordings.

3. RESULTS AND DISCUSSION

The median of Ae/G at each time window for 13 recordings was shown in Fig.1. As seen from Figure 1, there is a noticeable increase of Ae/G at seizure onset for most crisis. Furthermore, Increase of Ae/(B+G) can also be observed with seizure onset for most recordings.

Figure 1. Selective results: time evolution of median value of Ae/G for 13 crisis (Each color corresponds to one recording)

In this paper, a neural mass model was fitted to clinical iEEG recordings and key parameters were identified through exhausted search. A clear increase of Ae/G and Ae/(B+G) was observed for most recordings, indicating that the impairment of balance between excitation and inhibition may be one possible explanation for seizure crisis. Further quantitative analysis will be conducted to solidate the results.

References

DESIGN AND IMPLEMENTATION OF A MULTIDIMENSIONAL BALLISTOCARDIOGRAPH SYSTEM FOR AUTOMATED MONITORING OF CARDIAC CONTRACTILITY

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Keyword(s): biosignals – medical/clinical engineering

1. INTRODUCTION

Ballistocardiography (BCG) is a non-invasive technique used for monitoring the cardiac activity. The heartbeat and motion of blood into the main arteries cause tiny vibrations of the human body. The strength of these vibrations is measured with accelerometers placed at the surface of the body on the sternum or on the lower back. The acquisition on the sternum is called seismocardiography (SCG), while the acquisition on the lower back is called ballistocardiography (BCG). The amplitude of these accelerations is related to parameters of cardiac contractility\textsuperscript{[1]}. Moreover, it has been proposed that the left ventricle twist could be estimated through angular acceleration measurement\textsuperscript{[2]}. None of the current existing BCG & SCG implementations acquire angular accelerations. In this work, a system designed to acquire three leads ECG, 3D linear accelerations and 3D angular accelerations at both sternum and lower-back position is presented.

2. MATERIALS AND METHODS

A system including ECG, 6D SCG and 6D BCG was implemented. A microcontroller from the ST family is used to drive a 2 channels ECG ADC and a 16 channels ADC from the TI family. The last one is used to convert data coming from two analogue 3D accelerometers and two analogue 3D gyroscopes placed at the sternum on the apex level and on the lower-back of the subject. The acquisition is driven by the ECG ADC interrupts at 250 Hz sampling rate.

3. RESULTS AND DISCUSSION

The proposed system could easily be converted to a portable device. BCG and SCG signals acquired show very clearly the pattern related to the heart-beat (Figure 1). Moreover, the gyroscopes acquisition also shows patterns which were not reported in literature. However, the signals are still very sensitive to interferences, especially subject movements. Signal processing techniques, such as Ensemble Averaging, could greatly improve signal robustness. If an appropriate post-processing algorithm is applied, physiological parameters related to the heart mechanical function could be derived. This would allow the heart contractility to be assessed in a non-clinical environment which could potentially reduce the number of tests that currently needs to be done via costly medical machines such as cardia MRI and Doppler Ultrasound Echocardiography.

Figure 1: ECG-SCG Acquisition with the system. SCG\textsubscript{x,y,z} are the linear accelerations. SCG\textsubscript{rx,ry,rz} are the angular accelerations.

References


EFFECT OF FOOD AND MEALS ON ECG DYNAMICS

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Keyword(s): biosignals

1. INTRODUCTION
Sudden cardiac death is one of the major causes of cardiovascular mortality. It has been demonstrated that a prolonged QTc interval could create an electrophysiological environment that favors the development of cardiac arrhythmias. This study aimed to investigate the effect of standardized meals on the QTc interval whilst following a structured sequence of activities.

2. MATERIALS AND METHODS
Following a ten hour fasting period, ten healthy subjects (5 men, 5 women) were continuously monitored during a strict time protocol. They were instructed to consume two standardized meals, breakfast (510kcal) and lunch (750kcal), and perform a fixed sequence of activities before and after each meal: 10min supine resting, 5min standing, a 6min hall-walk test and 14min of supine recuperation.

The great morphological variation in ECG signals makes it hard to design an automated and widely applicable T wave end detection algorithm, yet various methods have been proposed. A first objective was to perform an objective comparison of four standard T wave end detection algorithms, with the manually annotated T wave ends of the PhysioNet database as a reference.

The first method was a semi-automatic method, based on a template matching algorithm. The second method determines the end of the T wave using the tangent of the steepest point of the descending limb of the T wave. The third and fourth method perform a maximum area search of, respectively, a trapezium and the area under the curve. In order to evaluate the accuracy and repeatability of the proposed algorithms, the mean and standard deviation (sd) of the detection errors were computed for lead II.

The most accurate method was used to compute the QT intervals during the activity protocol. Subsequently, the QT intervals were corrected by the Framingham method.

3. RESULTS AND DISCUSSION
We demonstrated that the trapezium method is the least repeatable (sd=46.8ms) of all methods tested, while the tangent method is the most repeatable one (sd=18.8ms). The integral method scores best in terms of accuracy (mean=1.4ms) and hence was used to compute the T wave ends during the activity protocol.

The main result of this analysis was the prolongation of the QTc interval in the supine position (10±2ms) after a high caloric meal (750kcal) and the fact that it lasted when the subject changed the position to upright. This is in agreement with the findings of Nagy et al. who reported an almost immediate prolongation in QTc after meal intake [1]. However, it did not confirm the QTc shortening demonstrated by Taubel et al. [2]. In the latter study subjects were instructed to commence bed rest, yet it lasted another 40 minutes before the first ECG recording. Since the supine resting phases in our study were recorded 10 and 5 minutes after respectively breakfast and lunch, both findings do not exclude each other.

We can conclude that a high caloric meal has a significant influence on the QTc interval when in the supine position.

References
SEMIAUTOMATIC NON-CONVULSIVE EPILEPTIC SEIZURE DETECTION USING MULTI-WAY DATA ANALYSIS

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Keyword(s): biosignals

1. INTRODUCTION

Non-convulsive status epilepticus is defined as 30 minutes or more of: a) continuous seizure activity or b) repetitive seizures without full return of consciousness between them [1]. This condition is common in critically ill patients from intensive care units. Since irreversible neurological damage could appear after 30 min of ongoing seizure activity it constitutes a medical emergency.

This paper proposes a semiautomatic method to detect non-convulsive epileptic seizures (NCESs) in order to diagnose non-convulsive status epilepticus. To perform the NCESs detection multiway data analysis will be used. The EEG will be represented as a third order tensor in the way $A \in \mathbb{R}^{F \times T \times C}$ with axes ‘frequency × time ×channel’. Seizure detection will be performed with the resulting signatures from the tensor decomposition. For the classifier training only the signatures obtained from the first NCES (marked by the doctors) will be used and the EEG prior to this NCES.

2. MATERIALS AND METHODS

2.1 EEG Data

The EEG data were obtained from 16 subjects aged between 18 and 57 years old. A total of 141 seizures are registered. All consistent to NCES without and with coma/stupor. Since the subjects come from different hospital services, the acquisition protocol differs among the data. The sampling rate for all recordings is 200 Hz.

2.2 Seizure Detection

Each recording was divided in epochs 3s duration, without overlapping. All epochs were transformed in the time-frequency domain, using both the Wavelet Transform (WT) and the Hilbert-Huang Transform (HHT). A 3rd order tensor was built for every epoch. The tensors were decomposed using the Canonical Polyadic Decomposition (CPD) and Block Term Decomposition (BTD).

The classification process was performed in two stages: (1) with each signature separately, (2) with Space and Frequency signatures assembled. A total of 7 classifiers were tested. To assess the classifiers performance four metrics are used, sensitivity, precision, accuracy (ACC) and false negative fraction (FNF).

3. RESULTS AND DISCUSSION

Among the classifiers the best performance was displayed by K-nearest neighbor classifier (KNN) for the Space signature. Table 1 shows the accuracy performance of the best classifiers for this signature. The precision and sensitivity average values obtained for this signature were 98.3% and 96.9% respectively.

Table 1. Best classifiers accuracy values for Space signature (All values are given in %).

<table>
<thead>
<tr>
<th></th>
<th>KNN</th>
<th>SVM</th>
<th>SVMR</th>
<th>BAYES</th>
</tr>
</thead>
<tbody>
<tr>
<td>H_spac_CP</td>
<td>97.0</td>
<td>96.1</td>
<td>94.2</td>
<td>97.8</td>
</tr>
<tr>
<td>W_spac_CP</td>
<td>72.0</td>
<td>80.0</td>
<td>77.1</td>
<td>82.6</td>
</tr>
<tr>
<td>H_spac_BT</td>
<td>71.7</td>
<td>52.9</td>
<td>69.2</td>
<td>75.0</td>
</tr>
<tr>
<td>W_spac_BT</td>
<td>59.2</td>
<td>51.0</td>
<td>65.9</td>
<td>62.8</td>
</tr>
</tbody>
</table>

The individual signature training disclosed that the HHT tensor results were superior to those obtained for WT tensors. This may indicate that HHT frequency-energy-time distribution could be more useful to classify the NCES. Frequency-Space training outcomes do not outperform the results achieved for the Space signature. The obtained results are less accurate and the FNF values increased compared to the ones achieved by the Space signature training.

Regarding the decomposition method, it was clear that CPD computed signatures fitted better the NCES data than BTD.

References

ALGORITHM FOR DETECTING ABNORMAL HEARTBEATS USING TENSORS AND SUPPORT VECTOR MACHINES

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Keyword: biosignals

1. INTRODUCTION
In a previous work [2], we introduced a new algorithm for detecting irregular heartbeats in ECG signals using Canonical Polyadic Decomposition (CPD) and Support Vector Machines (SVM). CPD is unique up to unavoidable permutation and scaling indeterminacies. However, such indeterminacies may change the input space of the classifier which will imply a re-training of the SVM.
This paper addresses this problem through the introduction of two new stages in the algorithm’s workflow.

2. MATERIALS AND METHODS
The figure below shows the algorithm’s workflow.

After CPD, two new stages were introduced (thicker lines in the figure). Both stages, Normalization and Principal Component Analysis (PCA) ensure that permutation and scaling indeterminacies do not change the input space of the classifier provided that CPD is essentially unique. The normalization stage handles the scale indeterminacy while PCA deals with the permutation indeterminacy. The PCA’s stage output is the input of a binary linear SVM classifier. Each SVM was trained to classify abnormal versus normal heartbeats. The training set was randomly selected using 2% of the available patterns in each record and 98% was used as testing set. The dataset is from the St.-Petersburg Institute of Cardiological Technics 12-lead Arrhythmia Database (INCARTDB) available on Physionet [1].

3. RESULTS AND DISCUSSION
The table shows (in bold) the global performance indexes of the classifiers. Below, the reference values are given for the classifiers without the stages introduced above [2].

<table>
<thead>
<tr>
<th>Se(%)</th>
<th>Sp(%)</th>
<th>Ppv(%)</th>
<th>Acc(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>93.66</td>
<td>97.80</td>
<td>86.20</td>
<td>97.27</td>
</tr>
<tr>
<td>93.90</td>
<td>97.70</td>
<td>85.72</td>
<td>97.22</td>
</tr>
</tbody>
</table>

The introduction of both stages avoids the re-training of the classifier and maintains the same global performance. The study suggests that this algorithm is feasible for detecting abnormal heartbeats. Moreover, the new stages provide consistency and flexibility to the original method.

References
ONLINE EPILEPTIC SEIZURE DETECTION AT HOME: A MULTIMODAL APPROACH

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Keyword(s): biosignals

1. INTRODUCTION

Epilepsy is one of the most common neurological disorders and it is affecting almost 1% of the population worldwide. Children are the most vulnerable group of these epilepsy patients. Having epilepsy has a major impact on their life, but also their parents are facing hard times. They want to help their child when he or she has a seizure.

Therefore a long-term home monitoring system is needed, that warns the parents in case of a seizure event. As EEG is not suitable in a home-situation, the monitoring system is based on other biomedical signals: Accelerometry (ACM), surface electromyography (EMG) and electrocardiography (ECG) [1]. This monitoring system will focus on two types of seizures: Tonic-Clonic (TC) and Hyperkinetic frontal lobe (H) seizures.

2. MATERIALS AND METHODS

The data is collected in the Pulderbos Rehabilitation Center for Children and Youth. During the acquisition ACM on both wrists and ankles, EMG on left and right biceps, two-lead ECG are recorded simultaneously with a sampling frequency of 250Hz. The data set consists of 7 patients with 21 TC seizures with a seizure duration of at least 10s and 205 hours of recording, 9 patients with 67 H seizures and 684 hours of recording.

In a first step, an online automatic seizure detector for each of the 3 mentioned signals is proposed.

The EMG/ACM detection is based on a LS-SVM classifier. Feature selection is done with the maximal relevance minimal redundancy (mRMR) technique, followed by a backwards wrapper feature selection.

The ECG detection starts with a Pan-Tomkins algorithm to extract the heart rate (HR). A real HR increase is detected, when there is a HR increase of at least 20 bpm, the peak HR is higher than 90 bpm, the HR gradient is at least 0.4 bpm/s and the length of the HR increase is at least 13 heart beats. In this case features are extracted and fed to a SVM classifier.

The multimodal algorithm combines the outputs of the algorithms applied on the sensors separately by using a late integration approach. A seizure is detected when at least 3 sensors (at least 1 EMG or ECG) are active in a time span of 5s.

3. RESULTS AND DISCUSSION

In table 1 the results of the individual sensors and multimodal algorithm are shown. The average sensitivities, false detection rates per hour (FDR/h) and delays, which is the time between the EEG onset and detection, are calculated for both the TC patients and H patients.

Table 1: Results TC / H patients

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Sensitivity [%]</th>
<th>FDR/h</th>
<th>delay [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACM</td>
<td>80.95 / 77.74</td>
<td>1.70 / 1.89</td>
<td>15.02 / 6.08</td>
</tr>
<tr>
<td>EMG</td>
<td>90.39 / 57.53</td>
<td>2.35 / 1.05</td>
<td>5.75 / 6.44</td>
</tr>
<tr>
<td>ECG</td>
<td>88.46 / 70.90</td>
<td>1.72 / 1.60</td>
<td>6.9 / 10.13</td>
</tr>
<tr>
<td>Multimodal</td>
<td>85.71 / 86.51</td>
<td>0.60 / 0.61</td>
<td>8.46 / 6.95</td>
</tr>
</tbody>
</table>

The EMG sensors have a lower sensitivity for the H group, which is due to the lack of a tonic phase. The delay of the ACM sensors in the TC patients is longer, due to the fact that the clonic phase comes after the tonic phase. The multimodal algorithm greatly reduces the FDR/h.

References

Medical Imaging
LÖWNER BASED RESIDUAL WATER SUPPRESSION IN MAGNETIC RESONANCE SPECTROSCOPIC IMAGING

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Keyword(s): Medical imaging, Biosignals.

1. INTRODUCTION

Magnetic resonance spectroscopic imaging (MRSI) signals are often corrupted by residual water and artefacts. Residual water suppression plays an important role in accurate and efficient quantification of metabolites from MRSI. In general residual water is suppressed in the pre-processing step using a filter based method \cite{1} or a subspace based method \cite{2}. Tensorizing the matrix and using suitable tensor decompositions provide certain advantages \cite{3}. In this work, a tensor based algorithm was developed to suppress the residual water simultaneously from all the voxels in the MRSI signal.

2. MATERIALS AND METHODS

The spectrum in each voxel is modelled as a sum of single pole rational functions. For each voxel in the MRSI grid, a Löwner matrix is constructed from its spectrum. A 3-D tensor is constructed by stacking the Löwner matrix from all MRSI voxels in the third mode. Canonical polyadic decomposition (CPD) is then applied on the tensor to extract the individual rational function. The parameters of the rational function containing resonance frequency and damping factors are estimated from the mode-1 and mode-2 factor matrices obtained from CPD using least squares. The water component is constructed using only those sources whose resonance frequency is outside the region of interest (0.25 - 4.2 ppm). Finally, the water is suppressed by subtracting the water component from the measured MRSI spectra. This method is further improved by adding polynomial sources to model the water component along with the rational functions.

3. RESULTS AND DISCUSSION

The performance of the proposed method is tested using both simulated and in-vivo 1H MRSI signals. In the first simulation a simple water model is used; here the Löwner method performs better than the widely-used subspace-based HLSVD method, which works on a Hankel matrix from one spectrum at a time. In the second simulation the water signal is distorted using a decaying exponential, here the basic Löwner method introduces some baseline. The Löwner method with polynomial sources can handle this problem and performs better than HLSVD. On the in-vivo 1H MRSI data both basic Löwner and HLSVD had similar performance, however the Löwner method with polynomial sources performed significantly better in suppressing the residual water signal.

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References


CHARACTERIZING MICROSTRUCTURAL ALTERATIONS IN A RAT MODEL OF MILD TRAUMATIC BRAIN INJURY

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Keyword(s): Medical Imaging

1. INTRODUCTION

Traumatic brain injury (TBI) is an acquired brain injury that contributes to a substantial number of deaths (mortality rate: 15 per 100 000 in Europe) and a high number of cases of permanent disability (incidence rate: 235 per 100 000 in Europe). Most of the TBI patients have mild TBI (mTBI), a condition that shows no abnormalities on conventional imaging but can result in persisting cognitive defects. Diffusion imaging is an MRI technique sensitive to diffusion of water molecules in the brain and can detect subtle changes in white matter organization. The aim of this study is to investigate whether advanced diffusion MRI scanning can be used to detect microstructural changes in a rat model of mTBI.

2. MATERIALS AND METHODS

2.1 Animal model

Nine female Wistar rats weighing 250 ± 19.6 g obtained mTBI utilizing the Marmarou weight drop model [1]. In brief, in anesthetized rats a steel helmet was fixed on the skull 1/3 before and 2/3 behind bregma. The rat was positioned under a 450 g brass weight on a foam bed. The weight was dropped from a height of 1m guided through a plexiglass column. The foam bed together with the rat was rapidly removed away from the column to prevent a second injury. Rats were allowed to recover for one week.

2.2 Imaging and data analysis

MRI data was acquired on a 7T MRI scanner (PharmaScan, Bruker, Ettingen) before and 1 week after injury. T2-weighted images were acquired for anatomical reference. Multishell diffusion data was acquired with multiple directions (b=800, 1500 and 2000; 32, 46 and 64 directions, respectively). Diffusion weighted images were corrected for EPI, motion and eddy current distortions and quantitative maps were calculated for the diffusion tensor and diffusion kurtosis model in ExploreDTI [2]. Furthermore diffusion kurtosis tensor estimation was done using weighted linear least squares method and maps for white matter metrics were calculated using the model of Fieremans et al. [3]. The maps were co-registered in SPM12 with a template based on the local population and a volume-of-interest analysis was performed in the hippocampus, cingulum and corpus callosum using Amide toolbox [4]. Differences between the two time points were calculated for each map using the Wilcoxon signed-rank test in SPSS. P < 0.05 was considered significant.

3. RESULTS AND DISCUSSION

The DTI and DKI metrics were not significantly different between the two time points. The axonal water fraction (AWF) was significantly increased in the cingulum, corpus callosum and hippocampus after mTBI and could be explained by axonal swelling. To verify this hypothesis, histological analysis is currently ongoing. Sections will be stained for synapses, astrocytes, neurons and myelin.

References

MAPPING MESH TOOL FOR LEFT VENTRICLE MODELING

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Keyword(s): medical imaging – medical/clinical engineering

1. INTRODUCTION

Vortex formation is an important mechanism in physiological Left Ventricle (LV) fluid dynamics contributing to efficient emptying of the LV and prevention of stasis [1], but is difficult to measure directly in vivo.

Thus, the aim of this project is to develop a computational fluid dynamics (CFD) model with prescribed moving boundaries of the LV wall derived from MRI imaging that can provide tools for quantitative assessment of intra cardiac flow.

2. MATERIALS AND METHODS

The conceptual framework of the CFD model is to derive the reference meshes from MRI acquisition and, due to the low temporal resolution of this technique, create intermediate configurations by means of cubic interpolation. The derived LV configurations will be assigned as displacement to the fluid domain (in Fluent software environment) by means of spatial interpolation.

In order to replicate and impose the LV wall displacement (as derived from clinical images) a Mapping Tool is needed to obtain conformal meshes that share the same topology and number of nodes throughout the cardiac cycle. In this way, the displacement of each node can be assigned univocally in the CFD model. Bavo et al. [2] developed a mapping method that has been applied to 3D ultrasound data, but the method is cumbersome and often results in distorted meshes.

A new method, based on isoparametric transformations, has been developed as part of this project and was applied to the LV data as used by Bavo et al. This tool was realized in PyFormex, an in-house python-based software.

The mapping tool can be described in the following steps:

1. Define the original patch
2. Define the initial control points (CPs) in the original patch
3. Place the final CPs in the LV surface at t0.
4. Apply the isoparametric transformation.
5. Manually pull the CPs of the previous LV configuration to fit the shape of the successive LV configurations for the entire cardiac cycle.

3. RESULTS AND DISCUSSION

Two different mappings have been performed, the coarser with 97 CPs and the finer with 484 CPs, to evaluate the spatial accuracy and mesh quality of the mapping tool. For the coarser meshes the mean and maximum difference in volume (as compared to the reference) were 2.4% and 3.9% respectively, while for the finer mesh values were 0.6% and 1%. The skewness was below 0.9 for all the LV mapped meshes and even for the worst result, 90% of the elements had skewness values below 0.5.

The developed Mapping Tool allows to create high quality meshes giving the chance to instantly change the type (quadrilateral, triangular) and number of elements. Further steps will be focused on the automatization of the tool.

Acknowledgement statement

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References

WHOLE-BODY DIFFUSION-WEIGHTED MR IMAGE MOSAICKING AND ALIGNMENT TO ANATOMICAL MRI

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Keyword(s): medical imaging

1. INTRODUCTION

Whole-body diffusion-weighted (wbDWI) MRI in combination with anatomical MRI has shown a great potential in bone and soft tissue tumour detection, evaluation of lymph nodes and treatment response assessment. Because of the vast body coverage, whole-body MRI is acquired in separate stations, which are subsequently combined into a whole-body image. However, inter-station and inter-modality image misalignments can occur due to image distortions, and patient motion during acquisition, which may lead to inaccurate representations of patient anatomy and hinder image visual assessment. Automated and accurate whole-body image formation and alignment of the multi-modal MRI images is therefore crucial. We previously investigated strategies for mosaicking DW image stations to form a wbDWI image. We found that, among the methods compared, pairwise registration driven by computing the mean squared differences between the maps of apparent diffusion coefficient (ADC) of the image stations performed best, and outperformed approaches described in literature [1]. In this study we addressed the issue of whole-body DW image formation and alignment with whole-body anatomical sequences, for the purpose of obtaining whole-body multi-channel (i.e. fully aligned) multi-modal MR image of higher quality.

2. MATERIALS AND METHODS

In this work, we compared a pairwise mosaicking approach, where diffusion-weighted (DW) image stations were sequentially aligned to a reference station (pelvis), to a groupwise approach, where all stations were simultaneously mapped to a common reference space while minimizing the overall transformation. For each, a choice of input images (i.e. ADC, b0) and corresponding metrics was investigated. As a second step, obtained wbDWI images were deformably registered to whole-body T1 reference image. To assess the performance of the registration methods thirteen whole-body MR image sets, consisting of 3D T1 anatomy and isotropic diffusion-weighted images were used. Four types of validation metrics were introduced: three for assessing the quality of the mosaicking of the wbDWI images and one for evaluating the alignment between diffusion-weighted and anatomical images.

3. RESULTS AND DISCUSSION

Image mosaicking methods based on a pairwise metric showed marginally better performance than groupwise method, independent of the type of image used for the registration. On the other hand, groupwise method resulted in more accurate image alignment for DWI to T1 whole-body image alignment (p<0.01). We hypothesize that such a process of minimizing 'global' transformation between the neighboring stations by a groupwise metric avoids bias created by sequential mosaicking and therefore, more precise initialization of wbDWI to T1 deformable registration.

The proposed groupwise method is a fully automated algorithm and was found to be robust making it feasible to be used in the clinic in order to further improve whole-body DWI and multi-channel MRI image quality.

References

CLASSIFYING GBM FOLLOW-UP OUTCOME USING SEMI-
MANUAL DELINEATIONS AND MULTI-PARAMETRIC MRI

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Keyword(s): medical imaging

1. INTRODUCTION

Delineating contrast enhancing (CE) tissue on T1 post-contrast Magnetic Resonance Images (T1pc MRI) is a key part of the Response Assessment in Neuro-Oncology (RANO) criteria for therapy follow-up in high-grade gliomas. The focus of this study is two-fold: (1) to evaluate the impact of semi-automatic delineation of hotspots of CE (HCE) in brain tumour follow-up of glioblastoma multiforme (GBM) patients after surgery, and (2) to evaluate results obtained by conventional and advanced MRI.

2. MATERIALS AND METHODS

Twenty-nine GBM patients who underwent surgery were scanned using a 3T MRI unit (Philips Achieva, Best, Netherlands). The protocol consisted of conventional MRI (cMRI: T1pc and T2), diffusion kurtosis imaging (DKI), and perfusion-weighted MRI (PWI: dynamic-susceptibility weighted contrast MRI). Regions of interest (ROIs) were manually drawn on T1pc images by an expert radiologist around the solid contrast-enhancing (CE) and Total tumour [1]. Another ROI was drawn around the contralateral normal appearing white matter to standardize MRI measurements. A label (responsive or progressive) was put on each patient according to the RANO criteria. We create another set of ROIs in the following way: for each session of each patient we use the T1pc intensities of all manually delineated voxels (Total ROI) and set an intensity threshold at the 90% percentile (P90). Voxels having intensities higher than or equal to P90 belong to HCE. After quantifying advanced MRI we obtain Cerebral Blood Volume and Cerebral Blood Flow from PWI, and Fractional Anisotropy and Mean Diffusivity from DKI. To these we add the two conventional maps, T1pc and T2, summing up to 6 parameter maps. For each time point of each patient, we perform an affine coregistration of the parameter maps to the T1pc map. For each parameter map and for both CE and HCE we compute the average and the 90th percentile of voxel intensities. In total, from 29 patients, we have 43 data points with manual CE ROIs, each with 12 features. After using our method to impute features, we obtain a 55 points dataset.

3. RESULTS AND DISCUSSION

We tune Support Vector Machines with Gaussian kernel on separate feature subsets and report the balanced accuracy rate (BAR).

<table>
<thead>
<tr>
<th>BAR (%)</th>
<th>cMRI</th>
<th>PWI</th>
<th>DKI</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE (43 points)</td>
<td>48</td>
<td>76</td>
<td>76</td>
<td>54</td>
</tr>
<tr>
<td>HCE (43 points)</td>
<td>84</td>
<td>69</td>
<td>74</td>
<td>83</td>
</tr>
<tr>
<td>HCE (55 points)</td>
<td>85</td>
<td>89</td>
<td>56</td>
<td>85</td>
</tr>
</tbody>
</table>

Using CE features on the 43 points dataset the maximum BAR is 76% for PWI or DKI subset. Using HCE features on the same 43 points dataset the maximum BAR is 84% for cMRI. Using HCE features on the extended 55 points dataset the maximum BAR is 89% for PWI, followed by 85% for cMRI.

Semi-automatic delineations can improve classification of progressive vs. responsive patients. Moreover, data imputation using our method allows for more accurate classification.

References

CONE-BEAM COMPUTED TOMOGRAPHY CAN QUANTIFY BONE MICROSTRUCTURE FOR ORTHOPAEDIC PURPOSES
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Keyword(s): medical imaging

1. INTRODUCTION

Micro-computed tomography (µCT) has become the gold standard in three-dimensional (3D) imaging of trabecular bone structure. Yet, usage is limited to ex vivo analyses, hence, it cannot be used to evaluate bone and bone adaptive responses in a patient. High-resolution peripheral computed tomography (HR-pQCT) is considered the best technique to measure the bone microarchitecture in vivo. Yet, by design HR-pQCT is limited to scanning extremities, such as the distal radius and distal tibia with a limited field of view. Cone-Beam Computed Tomography (CBCT) is a promising alternative with a much larger field of view allowing. Yet, CBCT is challenged by low image contract and artifacts that reduce image contrast, such that it currently is being used for qualitative evaluation only. Therefore, the goal of this work was to improve image contrast that would allow for quantitative CBCT analyses.

2. METHODS

18 trapezium bones of female arthritic patients were scanned twice ex vivo; once using the CBCT-scanner NewTom 5G (QR, Verona, Italy) and once using the microCT-scanner SkyScan 1172 (Bruker, Kontich, Belgium) at a resolution of 19.84 µm. The CBCT-scans were reconstructed following 2 protocols: (1) using the commercial software delivered with the scanner (at a resolution of 75 µm) and (2) using an own in house developed multithreaded FDK reconstruction program (at a resolution of 60 µm). The transmitted flux, I₀, in the law of Lambert-Beer was estimated on a blank scan and the projection data was corrected for current modulation. After reconstruction, the images were segmented using adaptive thresholding and bone morphometric parameters including bone volume (BV), total tissue volume (TV), percent bone volume (BV/TV), bone surface (BS), trabecular thickness (Tb.Th), trabecular separation (Tb.Sp) and trabecular number (Tb.N) were calculated. Statistical evaluations were made at a significance level of 1%.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>µCT Mean</th>
<th>CBCT QR Mean</th>
<th>Own CBCT Mean</th>
<th>R² µCT</th>
<th>R² CBCT QR</th>
<th>R² Own CBCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BV/TV [%]</td>
<td>33.64</td>
<td>50.95</td>
<td>66.00</td>
<td>0.68</td>
<td>0.74</td>
<td>0.93</td>
</tr>
<tr>
<td>BS [mm²]</td>
<td>10498</td>
<td>6014</td>
<td>7670</td>
<td>0.83</td>
<td>0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>Tb.Th [mm]</td>
<td>0.24</td>
<td>0.55</td>
<td>0.44</td>
<td>0.05</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>Tb.Sp [mm]</td>
<td>0.55</td>
<td>0.68</td>
<td>0.58</td>
<td>0.74</td>
<td>0.92</td>
<td>0.92</td>
</tr>
<tr>
<td>Tb.N [1/mm]</td>
<td>1.42</td>
<td>0.93</td>
<td>1.06</td>
<td>0.49</td>
<td>0.55</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Table 1: Mean and R² correlation results of the µCT, CBCT QR (first protocol) and own CBCT (second protocol) data

3. RESULTS

For all bone parameters significant correlations were found between the in-house reconstructed CBCT-images and microCT-images. Poorer correlation were observed for all parameters using the manufacturers reconstruction and no correlation was found for the parameter Tb.Th. Yet, a significant overestimation was observed for BV/TV and Tb.Th and an underestimation for Tb.Sp and Tb.N.

4. DISCUSSION

We found that CBCT image contrast can be enhanced allowing for quantification of trabecular bone microarchitecture. Our findings compare favorably to that of the first generation HRpQCT. Artefact correction could further enhance CBCT quality and microstructural accuracy. Though the findings seem inferior in comparison with the second generation HRpQCT [2], the broader application of the CBCT-scanner and the larger field of view, makes the CBCT-scanner a valuable alternative for HRpQCT.

References

LAPLACIAN EIGENMAPS FOR MULTIMODAL GROUPWISE IMAGE REGISTRATION

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Keyword(s): medical imaging

1. INTRODUCTION

Biomedical image registration is a task commonly performed in medical image analysis. With most methods focused on the alignment of two images in so-called pairwise registration, groupwise registration is increasingly gaining interest to perform the registration for a group of images simultaneously. Applications where such a groupwise registration is of interest range from population atlases to the joint analysis of tissue properties in multimodal or multiparametric images.

In this work we present a novel dissimilarity metric for groupwise multimodal registration based on Laplacian eigenmaps \cite{1}. The metric was evaluated on one synthetic and two clinical datasets and showed increased accuracy and robustness compared to other state-of-the-art methodologies.

2. MATERIALS AND METHODS

Laplacian eigenmaps is a non-linear dimensionality reduction technique which allows data living on a high-dimensional manifold to be projected onto a lower number of dimensions whilst retaining the local structure of the manifold\cite{1}. The basic assumption is made that when the images in the group are near alignment, more variance is being captured by the projections on the first few dimensions.

In this work we propose to use the algebraic connectivity (i.e. the second smallest eigenvalue obtained from the eigenproblem defined in Laplacian eigenmaps) as a dissimilarity metric for groupwise multimodal registration. The proposed method was evaluated in the registration of two synthetic images with a non-linear intensity relationship and in two clinical multimodal datasets. The first dataset consisted of MRI sequences with different flip angles and echo times of the carotid artery and the second dataset consisted of CT, PET and MRI images of the brain. The proposed methodology was compared to two groupwise dissimilarity metrics based on principal component analysis.

3. RESULTS AND DISCUSSION

The experiment on the synthetic images reveals the correct minimization behavior for the proposed methodology as is shown in Fig. 1.

Figure 1: The metric behavior of the proposed metric compared to a PCA-based metric.

Furthermore, the proposed metric based on Laplacian eigenmaps showed an increase in accuracy from $1.15 \pm 0.45$ mm to $1.07 \pm 0.42$ mm in the first clinical dataset and an increase in robustness in the second clinical dataset. Herein, the number of misregistrations was reduced to 0 for the proposed metric, compared to 16 misregistrations (out of 18 registrations) for the metrics based on PCA.

References

INFLUENCE OF UNIFORM SCALING AS PART OF THE REGISTRATION STEP FOR THE CREATION OF A STATISTICAL SHAPE MODEL OF THE CLAVICLE

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Keyword(s): medical imaging – medical/clinical engineering

1. INTRODUCTION

The clavicle presents a large variability in its characterizing S-shape. Non-properly fitting fixation plates (FP) cause irritation of surrounding soft tissues and in many cases, these FP need to be removed. It is therefore key in FP design to account for shape variations. Statistical shape models (SSM) have been used to describe shape variations of bones. However, few studies [2,3] used SSM to describe the shape variations of the clavicle and only a limited set of samples were used. The goal of this study was to develop an algorithm for non-rigid registration resulting in a good geometric fit and mesh correspondences, such that resulting meshes can serve as input for principal component analysis (PCA).

2. MATERIALS AND METHODS

49 Clavicles were included: 11 Clavicle models were acquired by laser scans (Niko, LC60Dx), 38 clavicles were segmented from CT-scans (Mimics, Materialise, Belgium). Next, a source clavicle was registered to all other clavicles. Two registration variants, which extend the algorithm of Amberg [1], were implemented in Matlab (Mathworks, USA). Both algorithms consist of a rigid registration, followed by a two-stage non-rigid registration where first the corresponding points were selected by ray tracing, second the correspondences found by ray tracing were used to solve the optimal step non-rigid ICP algorithm for surface registration of Amberg. In the second algorithm however, the source mesh was scaled uniformly between the rigid registration and non-rigid registration step, to better match the target mesh. For both algorithms, an SSM was created.

3. RESULTS AND DISCUSSION

A mean geometric fit of -0.76 µm was achieved without scaling, compared to -0.24 µm by including scaling. The mean Euclidean distance between conoid tubercle in target mesh and deformed source mesh reduced from 6.69 mm without scaling, to 3.72 mm with scaling. To explain 95% of the variation in the population, the first algorithm required 12 principal components (PC) compared to 6 PC’s for the second algorithm. However, the PC’s remained similar between methods.

Results underline the importance of uniform scaling in the registration algorithm for the creation of an SSM and enables design optimization of clavicle FP. Since not all geometrical features of the clavicle influence FP design, future work will focus on an SSM of that part of the clavicle where contact between bone and plate is allowed.

References

Medical/Clinical engineering
WIRELESS TRANSFER SYSTEM FOR IMPLANTED GASTROSTIMULATOR

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Keyword(s): medical/clinical engineering.

1. INTRODUCTION
Power efficiency is critical for implanted electrical stimulators. These systems deliver large amount of power (i.e. stimulating current to the load) with a restricted power source. Wireless power transmission is therefore a common limiting factor.

Our group is working on an implanted gastrostimulator, aiming to produce a feeling of satiety, and hence to fight obesity [1]. Gastric electrical stimulation is a recent technique that uses an implanted device (gastrostimulator) to stimulate the stomach, aiming to produce a feeling of satiety for obese patients, and hence to fight obesity. It has recently shown promising effects in treating obesity and could potentially overcome most of the drawbacks of bariatric surgery, being less invasive, reversible and cost effective.

This paper presents the wireless power transfer system used for our gastrostimulator.

2. MATERIALS AND METHODS
Fig. 1 shows the block diagram of the wireless transfer system of our gastrostimulator.

The size of the implant is fixed, imposing its dimensions to the secondary coil. The primary coil was designed with a covered area 4.5 times bigger than the secondary, to ensure low sensitive to displacement.

The operating frequency was chosen equal to 300 kHz, which is allowable for medical devices. The portable wireless power generator includes batteries, a boost converter to raise the voltage to a usable value, a class E amplifier, and a microcontroller to easily generate and fine tune operating frequency.

3. RESULTS AND DISCUSSION
With the current configuration, a voltage of 5 V is retrieved at the secondary, which is sufficient to charge the battery. Our 90 mAh battery can be charged in approximately 2 hours when the distance between the primary and secondary coils is 1 cm. The efficiency of the system is 27%. We are currently working on a new power strategies to increase this efficiency.

References
GRANULAR JAMMING AS CONTROLLABLE STIFFNESS MECHANISM FOR ENDOSCOPIC AND CATHETER APPLICATIONS

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Keyword: medical/clinical engineering

1. INTRODUCTION

1.1 Context

During minimally invasive procedures, most of the devices (endoscopes, catheters, guidewires, etc.) need to be sufficiently flexible to avoid damaging patient tissues or causing pain, but have to be stiff enough to transmit force for support or e.g. puncture. In Fig.1, the problem of the vascular stenosis is illustrated. The guidewire has to be flexible to reach the stenosis, but it requires a rigid support to pass through the occlusion for treatment due to the force application. In order to solve this duality on the rigidity, controllable stiffness mechanisms can be used. Various mechanisms to control the stiffness can be found in the literature [1]. One of the promising solutions to achieve this objective is based on granular material jamming [2]. This research aims at studying the scaling laws of such solutions for miniaturized applications (with diameters below 3mm), the mechanical rules of design and the optimization based on the stiffness performances.

Fig.1 Vascular stenosis and medical intervention

1.2 Granular jamming

The granular jamming is based on the locking of granular material. In this study, a flexible membrane is filled with a granular material. When the pressure difference between outside and inside the membrane is low, the grains are free to move with respect to each other. In this configuration, the system is very flexible. Once the difference of pressure is increased, the grains are locked to each other due to the inter-grain friction. In this configuration, the system is more rigid.

2. MATERIALS AND METHODS

In this work, the performances of the stiffness change thanks to the granular jamming are quantified by mechanical tests. On the one hand, three point bending tests are performed to quantify the flexural stiffness (product of the Young Modulus and the second moment of area) of the solutions. Various granular materials and diameters of the samples are studied. On the other hand, triaxial compression tests are performed to observe the influence of the difference of pressure on the rigidity obtained via granular jamming.

3. RESULTS AND DISCUSSION

The tests described previously provide information on the performances of the granular jamming solution as well as an indication of the most important parameters to optimize. The results of the triaxial compression tests show that the pressure difference is the most important parameter influencing the Young Modulus. The bending tests show that the second moment of area greatly impacts this stiffness. Removing the influence of the geometry, the equivalent Young Modulus is positively influenced for smaller diameters which is promising for the applications targeted in this work.

Acknowledgement

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References


SENSENDO: AN INSTRUMENTED TOOL AND FORCE FEEDBACK SYSTEM FOR THERAPEUTIC GASTROINTESTINAL ENDOSCOPY

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2 Université libre de Bruxelles, Laboratory of Experimental Gastroenterology, Belgium

Keyword(s): medical/clinical engineering

1. INTRODUCTION
Natural orifice transluminal endoscopic surgery (NOTES), covering all the scarless surgical procedures exploiting the natural orifices of the human body, has been trending upward since the early 2000’s. In gastroenterology, physicians are performing therapeutic procedures of increasing complexity, thanks to the development of new instruments, technologies and procedures. One of the restrictions imposed by endoluminal techniques is the loss of tactile feedback the physician would have with open surgery. This lack, which is due to the friction forces occurring in the endoscope, can be problematic when injections must be performed at a precise depth of the gastrointestinal wall. The latter being composed of layers (mucosa, submucosa, muscularis and serosa) [1], the piercing force reflects the transitions between the layers. To compensate the loss of this precious information, the Sensendo project was created, aiming at developing an endoscopic needle integrating a force sensor and a force feedback system restoring the distal force in the hand of the physician.

2. MATERIALS AND METHODS

2.1 Instrumented Needle
To allow the sensing of the axial force at the tip of the tool, a sensor† based on Fiber Bragg Gratings (FBG) technology was designed and integrated at the needle/catheter interface. The sensor has a diameter of 2.1 mm and can measure forces from 0 N to 4 N with a resolution of 1 mN. The needle passes through 2.8 mm working channels of gastroscopes. The fibers are interrogated by a dedicated instrument at a rate allowing the global force feedback loop to run at 1 kHz. The data is sent in real-time to the force feedback system.

Figure1: Force sensor CAD design.

2.2 Force Feedback System
The function of the force feedback system is to use the data from the previously described force sensor to give its feedback to the gastroenterologist. It is composed of a real-time computer, a motor controller and a motorized endoscopic handle. The computer reads the data from the FGB interrogator and controls the handle motor. An amplification factor can be introduced to achieve the desired feedback intensity. The handle has a fixed part to be connected on the entry of the working channel of the gastroscope and a mobile part to which the needle is locked and on which the force feedback is applied.

3. RESULTS AND DISCUSSION

The described system allows force feedback during injection procedures. It has been qualitatively tested on a phantom with good results. Next steps include quantitative testing on a phantom, isolated pig stomachs and then living pigs.

Further developments are necessary to improve the design of the sensor and make it more reliable and easier to assemble. Also, the ergonomics of the handle must be revised to better meet the gastroenterologists’ needs.

References
† Initial developments were made in collaboration with Prof. C. Caucheteur from UMons and Prof. M. Kinnaert from ULB.
BRONCHOSCOPIC NEEDLE EMBEDDING AN OPTICAL FIBER BIOSENSOR

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Keywords: bio-signals – medical/clinical engineering

1. INTRODUCTION

This research targets the development of a new class of real-time, in vivo, label-free biosensor based on functionalized Optical Fiber (OF) gratings [1] for cancer detection. It targets Minimally Invasive Medical Diagnostic (i.e. endoscopic and laparoscopic interventions).

The main idea behind this project is to propose to the doctors a faster, less-invasive and more reliable alternative to the current tools (a.k.a. biopsy needles and forceps) to diagnose a patient. Currently, real-time, in-vivo cancer detection techniques are under investigation, but none is yet commonly used by doctors.

One of the difficulties when working inside the lungs is the diameter of the bronchi that decreases from the 1st to the 23rd bronchi generation. With a commonly used bronchoscope with a distal external diameter of 6 mm, the doctors can only reach the 4th generation. This implies that the tools they insert after the 4th generation are usually oriented thanks to the extension/flexion abilities of the bronchoscope, stuck at the 4th generation of bronchi. When there is a need to reach hardly accessible regions of the lungs (i.e. the apical region), the doctors then use highly flexible tools (i.e. forceps) and steerable catheters.

2. MATERIALS AND METHODS

The biosensor consists of a functionalized Tilted Fiber Bragg Grating inscribed in the core of the fiber with an external tilt angle of 7°. Briefly, 1 cm of a stripped OF is used as the sensitive area. The bronchosopic needle was designed following a literature review about the influence of the tip shape, tip angle and tip velocity on the force required to pierce soft tissues. Tow optical fiber biosensors can be embedded in the core of the bronchosopic needle shown in Figure 1. A side aperture is patterned at the side of the distal tip in order to expose the biosensor when required.

![Figure 1: POM bronchoscopic needle with the window patterned below the distal conical tip.](image)

3. RESULTS AND DISCUSSION

A reliable signal was successfully obtained in a buffer solution as well as in a solid medium. The navigation inside the lungs of a living pig was successful. The loss in flexion and extension was respectively of 1.25% and 11.8% between our device and a biopsy forceps currently used by the endoscopists. The bronchoscopic needle was successfully observed under X-Ray while navigation inside the lungs of a living pig. Finally, we successfully obtained a signal in an ex-vivo human lung sample obtained after a lobectomy.

The focus is now on improving the detection technique and on improve the navigation of the bronchosopic needle by upgrading it to a smart steerable needle.

References

SIZE MEASUREMENT DEVICE FOR ENDOSCOPIC APPLICATIONS

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Keyword(s): medical imaging, medical engineering

1. INTRODUCTION

Size measurement is an unmet need in the field of endoscopy, particularly in the screening of colorectal cancer.¹ Endoscopists need to estimate polyp size to properly diagnose the cancer evolution. Current inaccurate measuring methods lead to the misclassification of 24% of the polyps, leading to potential mistakes in the follow up of the patient or to inappropriate resection method. In this research, a measurement method has been developed to provide endoscopists an accurate measurement method.

2. MATERIALS AND METHODS

The system is based on structured light; a pattern is projected using a diffractive optical element (DOE) that diffracts a laser beam transmitted using an optical fiber. Based on the properties of epipolar geometry, a line is projected and analyzed to find the 3D coordinates of all line points. The projection device is embedded on an endoscope. The system is calibrated in order to define the position of the projection device with respect to the camera. The results is then integrated on the endoscopic image.

3. RESULTS AND DISCUSSION

The system has been tested on a model of colon for preliminary tests and on isolated stomach pigs. It provides a way to measure with an accuracy of about 0.4 pixels [2] at any depth or 0.2 mm at a depth of 5 cm.

The system is shown Figure 1. The line is found by the algorithm and analyzed to provide the 3D coordinates of the points of interest. The polyp has a size of 6.9 mm. The calculation time is of about 30 ms per frame.

The system still needs to be developed in order to be tested on pigs and humans.

References


MECHANICAL PRESSURES – A NOVEL CANDIDATE PREDICTOR OF CONDUCTION DISTURBANCES AFTER TRANSCATHETER AORTIC VALVE IMPLANTATION

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Keyword(s): medical/clinical engineering

1. INTRODUCTION
Conduction abnormalities are one of the most frequent complications after transcatheter aortic valve implantation (TAVI) and they often lead to pacemaker implantation [1]. High pressures generated by the inserted device on the LVOT (left ventricular outflow obstruction) wall in vicinity of the conduction system might be the main cause of injury of the conduction system leading to these abnormalities. In this study, TAVIguide, a CE marked preoperative planning tool that allows patient-specific finite-element simulations of TAVI procedures, is used to investigate whether the pressures on the aortic wall as result of the interaction between the implanted device and the surrounding tissues are a candidate predictor of conduction abnormalities.

2. MATERIALS AND METHODS
Ninety-five patients, of whom 59 developed new conduction abnormalities after implantation of self-expanding CoreValve were enrolled (EMC Rotterdam, UZA Antwerp). For each patient, a 3D patient-specific aortic model was segmented from preoperative cardiac CT images (Mimics v18.0). The lower boundary of the membranous septum, which constitutes an anatomical landmark for the left ventricular exit of the His bundle, was identified in the 3D models starting from dedicated landmarks assessed on the preoperative CT images. Finite-element simulations were performed in Abaqus to virtually implant the Medtronic CoreValve device at the same implantation depth as done in reality for each patient. The maximum contact pressure in the selected region of interest was assessed.

A 2-tailed Mann-Whitney test was performed in SPSS to test pressure level differences between patients with and without conduction disturbances post-TAVI, with the significance level set at 0.05. Receiver-operating characteristic (ROC) curve and sensitivity-specificity analysis were performed for the investigated parameter.

3. RESULTS AND DISCUSSION
Anatomical variability on the membranous septum (location, length and shape) was observed in the investigated population. In the selected region of interest, significantly higher contact pressure values were observed in patients with new conduction abnormalities after TAVI (p<0.001). The area under the curve equal to 0.78 was obtained from the ROC curve analysis, showing good accuracy of the test. Furthermore, the pressure value of 0.36 MPa was identified as cut-off that maximizes sensitivity and specificity, resulting in a sensitivity of 84% and in specificity of 67%. Based on the obtained results, we conclude that the contact pressure is a potential predictor for new conduction abnormalities after TAVI.

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References
POSITION CONTROL OF ROBOTIC CATHETERS INSIDE THE VASCULATURE BASED ON A PREDICTIVE MINIMUM ENERGY MODEL

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Keyword(s): medical/clinical engineering

1. INTRODUCTION

Recent efforts in robotics and automation research have fostered the development of a wide variety of bio-inspired snake-like continuum robots. These robots require control schemes that are radically different from conventional rigid robots. Although they are receiving more attention in the scientific community, accurate and precise control of these robots – and, in particular, of robotic catheters – inside a deformable vasculature remains difficult. The absence of apparent rigid links and joints and the complex interplay between internal actuation forces, distributed external loads and intrinsic compliance of the robot make the formulation of their kinematics considerably more challenging compared to traditional robots. In particular, the distributed interaction forces between the catheter and the vessel wall largely affect the behavior of the catheter, but cannot be accurately measured with the current sensing technology. This work proposes to estimate the differential kinematics of robotic catheters from a minimum energy argumentation that predicts the behavior of the catheter inside a patient-specific vasculature model. The estimated differential kinematics can then be used in a conventional control scheme to steer robotic catheters. The proposed approach was evaluated through simulations and experiments in a 2D setup.

2. MATERIALS AND METHODS

The quasi-static minimum energy argumentation proposed in [1] was developed to predict the changes in the shape of a guidewire that result from specific positioning commands (e.g. insertion or rotation). For every command, the guidewire bending energy and guidewire-vessel interaction forces are estimated and used as inputs to iteratively compute the changes in the guidewire shape that would minimize the energy of the entire system. This argumentation is here expanded to robotic catheters to simulate active bending of the catheter. The kinematic map relating the catheter actuation variables to the position of the catheter tip is then estimated by virtually probing the robot joint space within the minimum energy model and monitoring the resulting tip displacements. This estimated kinematics can be seamlessly incorporated in a conventional scheme to control the catheter tip position. Note that, to avoid build-up of errors, sensory feedback is used to initialize the minimum energy model in every control step.

3. RESULTS AND DISCUSSION

The proposed approach is evaluated in both simulations and experiments in which a robotic catheter with a single active bending segment is inserted in a 2D vessel mock-up and needs to follow a target path. Results indicate that the predictive minimum energy approach can lead to accurate catheter control over a target path with a tracking error of about 1mm – as long as the internal actuators of the robot do not saturate. Important future work consists of broader validation of the approach using catheters with multiple bending segments and working with 3D deformable vessel models. Further efforts are necessary to reduce the high computational cost of the proposed approach. Finally, the influence of the sensory feedback on the control accuracy will be further investigated.

References

Tissue engineering
AN IN-SILICO MODEL OF BMP-2 CARRIER DEVICE FOR BONE TISSUE ENGINEERING APPLICATION

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Keyword(s): Tissue Engineering - Biomechanics

1. INTRODUCTION
To overcome the drawbacks of bone grafting techniques, tissue engineering aims to develop bone substitutes that can replace damaged, diseased or aging bone tissue. These substitutes are designed to support the chemotaxis, proliferation and differentiation of bone progenitor cells as well as being a biochemical agent delivery system, making them a promising alternative to bone grafting techniques. Of all the biochemical agents that have been identified so far, bone morphogenetic proteins 2 (BMP-2) is widely recognized to be one of the most powerful osteoinductive factors for bone regeneration [1]. In this study, we implemented a previously reported mathematical model [2] to elucidate the in vivo bone formation capacity of BMP delivery systems in an ectopic environment to investigate the influence of BMP-2 dose and BMP-2 device volume on bone formation.

2. MATERIALS AND METHODS
The previously established model [2] described the spatiotemporal evolution of various cells, growth factors and extracellular matrices involved in bone formation process (Fig.1). A set of 10 PDEs of the taxis-reaction-diffusion type captured the various key processes of bone regeneration at the intracellular, cellular and tissue level with appropriate initial and boundary conditions (Fig. 2). The model does not include bone remodelling. The performance of this model will be corroborated by experimental results reported in the literature [3].

3. RESULTS AND DISCUSSION
The resulting model predicts the influence of BMP-2 dose on bone formation (Fig.3 (a-b)). In the future, the influence of volume of BMP-2 carrier device on bone formation will also be investigated.

References
IMPROVING PERFUSION BIOREACTOR YIELDS BY USING PARTICLE SWARM OPTIMIZATION

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Keyword(s): biomechanics – tissue engineering

1. INTRODUCTION

Bone tissue engineering (TE) is a field that combines expertise from medical and engineering sciences to come up with solutions for large or non-healing bone defects. A widely used solution in TE is the combination of 3D porous scaffolds with cells, cultured in bioreactor systems. The use of computational models could play an important role to further elucidate the biological mechanisms of the neotissue growth within the scaffold [1] during bioreactor culture. Furthermore, computational models could be used to optimize the bioreactor settings leading to an increased neotissue production.

In this study we have developed a mathematical model describing the neotissue growth in the scaffold during bioreactor culture. We have applied particle swarm optimization (PSO) to the model in order to find the best refreshment regime which maximizes the final growth.

2. MATERIALS AND METHODS

Guyot et al [1] developed a model describing the neotissue growth in great detail, making it computationally very expensive. In this study, we have adapted the model in order to reduce the cost but to maintain a similar level of mechanistic detail by omitting all references to spatial heterogeneity.

In order to validate the developed mathematical model, experiments have been conducted by the researchers from the Tissue Engineering Unit of the Skeletal Biology and Engineering Research Centre of the KU Leuven. Figure 1 shows the comparison between experimental data and computational results for neotissue filling of a gyroid scaffold over 28 days of culture. As depicted, a good qualitative and quantitative correlation is obtained.

3. RESULTS AND DISCUSSION

In the bioreactor experiments, the entire medium supply (100%) flowing through the perfusion bioreactor is refreshed every 3 days - which might be a suboptimal regime. To find the best frequency of the medium refreshment along with the fraction of medium being refreshed to have the largest neotissue yield in 21 days of culture, we performed a PSO procedure. As depicted in figure 2, the blue circle shows the area with the optimal medium refreshment strategy. Further experimental validation is ongoing.

References

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